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Pediatric Out-of-Hospital Emergencies

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ACADEMIC DISSERTATION

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ABSTRACT

Only recently have an increasing number of studies and publications about children in prehospital care begun to emerge. A study by Harve et al. discovered that even though children form a small proportion of all emergency medical services (EMS) contacts, their care had several aspects that needed consideration. First, young children aged one or less were overrepresented in children's contacts with EMS. Second, falls, respiratory problems, seizures, and poisonings accounted for half of all of their emergencies. Finally, an unexpected number of children assessed by paramedics, was not transported to the hospital [1].

Rooted in the Harve group findings, this study explored EMS contacts with children in more detail, focusing on pediatric subpopulations such as children who had had seizures, infants, and children who after evaluation by EMS personnel were not transported to any health-care facility. In addition, the aim of the research was to identify risk factors for untoward outcomes in EMS contacts with children. Moreover, the study investigated whether and how the COVID-19 pandemic and restrictions intended to curb the pandemic impacted out-of-hospital (OOH) emergencies in children during the first wave.

The thesis consists of four register-based retrospective cohort studies conducted in the Helsinki University Hospital (HUH) area. Children under 16 years old formed the study population overall, except in the one study where the study population comprised 0- to 11-month-old infants. The data on EMS contacts were gathered from both OOH and in-hospital electronic patient-record systems (EPRS). The study periods lasted from three months to five years.

EMS contacts with children were rare, comprising from 3.9% to 4.8% of all contacts. Infants constituted about 0.4% of all EMS contacts. EMS contacts with children who suffered seizures occurred in the 13% of pediatric missions. The non-transportation rate was high and ranged from 26.7% in pediatric seizure patients to 60.1% in infants. The non-transportation seemed to be safe, and hospitalization or pediatric intensive-care unit (PICU) admissions were seldom necessary. On-scene mortality was low. Only a few patients died during follow-up periods, and none of these deaths were traceable to EMS contact.

The study recognized several risk factors for secondary outcomes after EMS contact with children. Dispatch codes ”dyspnea”, ”vomiting/diarrhea” and ”mental illness” were associated with unintended visit after non-transportation in general pediatric population. In infants, dispatch codes ”dyspnea” and ”urgent dispatch before symptom-specific code known”, as well as problems in the neonatal period were associated with hospitalization and PICU admissions. In contrast, dispatch code ”low-energy fall” was less associated with unintended visits after non-transportation, and hospitalizations and PICU admissions in infants.

Fewer EMS contacts with children occurred during the first wave of the COVID-19 pandemic. However, the proportion of children in the most urgently dispatched and transported priority category A rose significantly. In addition, EMS personnel requested additional help or mobile intensive-care unit (MICU) backup more frequently to the scene. Thus, children appeared to be acutely more ill during the restriction period. COVID-19 infection among children with EMS contact was infrequent.

In conclusion, EMS encounters with children were uncommon and around half of the children were not transported after evaluation by EMS personnel. The current practice appeared to be safe, when evaluated by hospitalization, PICU admissions, and mortality. The high non-transportation rate may reflect the changing role of EMS and possible non-medical needs of families with children. Taking into account the risk factors that were identified in this study could further improve patient safety among EMS contacts with children. Consideration that restrictions during the pandemic may have unexpected side effects on children's health may help to guide and direct restrictive measures during future sudden pathogen outbreaks.

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ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I. Oulasvirta J, Salmi H, Kuisma M, Rahiala E, Lääperi M, Harve-Rytsälä H. Outcomes in children evaluated but not transported by ambulance personnel: retrospective cohort study. BMJ Paediatr Open. 2019;3(1):e000523.

II. Salmi H, Oulasvirta J, Rahiala E, Kuisma M, Lääperi M, Harve H. Out-of-Hospital Seizures in Children. Pediatr Emerg Care. 2020;(Jan 22).

III. Oulasvirta J, Harve-Rytsälä H, Lääperi M, Kuisma M, Salmi H. Why do infants need out-of-hospital emergency medical services? A retrospective, population-based study. Scand J Trauma Resusc Emerg Med. 2021;29(1):13.

IV. Oulasvirta J, Pirneskoski J, Harve-Rytsälä H, Lääperi M, Kuitunen M, Kuisma M, Salmi H. Paediatric prehospital emergencies and restrictions during the COVID-19 pandemic: a population-based study. BMJ Paediatr Open. 2020;4(1):e000808.

The publications are referred to in the text by their roman numerals.

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ABBREVIATIONS

ALS	Advanced Life Support
ARDS	Acute Respiratory Distress Syndrome
BLS	Basic Life Support
COVID-19	2019 novel Coronavirus disease
CPR	Cardiopulmonary Resuscitation
ED	Emergency Department
EM	Emergency Medicine
EMS	Emergency Medical Services
EMT	Emergency Medicine Technician
EPRS	Electronic Patient-Record System
ERC	Emergency Response Center
ERMU	Emergency and Resuscitation Mobile Unit
HEMS	Helicopter Emergency Medical Services
HUH	Helsinki University Hospital
IBE	International Bureau for Epilepsy
ILAE	International League Against Epilepsy
im	intramuscular
io	intraosseous
IQR	Interquartile Range
iv	intravenous
MECU	Mobile Emergency Care Unit
MICU	Mobile Intensive Care Unit
NETS	Newborn and Pædiatric Emergency Transport Service
OOH	Out-of-Hospital
PECARN	Pediatric Emergency Care Applied Research Network
PICU	Pediatric Intensive Care Unit
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus
s.l.	sublingual

1 Introduction

Many aspects have to be considered when providing care to children in the out-of-hospial (OOH) setting: young children are not able to communicate clearly and are thus unable to narrate a reliable medical history or even explain what has happened or where does it hurt. Children express special physical and developmental characteristics, and their anatomy and physiology is age- and size-dependent. Teenagers may look like adults, but are developmentally children - especially in psychological development, which continues long after any observable physical changes [2]. The care of children, furthermore, almost always involves interaction not only with the patient, but also with the care-givers. Finally, contacts with children are infrequent for emergency medical serivces (EMS) personnel [1, 3–5], and weight-based medication dosing in addition to size-based equipment require special attention and alertness from EMS personnel [6–8].

Seizures are common in the pediatric population, but little is known about EMS contacts with children undergoing seizures. Although febrile seizures have a good prognosis [9], epilepsy may result in severe morbidity also in children [10]. In order to avoid prolonged convulsions and development of status epilepticus, seizure termination is essential [10]. EMS play a key role in recognizing seizures and providing vital treatment [10, 11].

Infants form a vulnerable and delicate subpopulation among EMS contacts with children [12, 13]. Even though their proportion of all EMS contacts is minor, they are overrepresented in pediatric EMS responses [1, 14]. Young children are also prone to adverse events in health care and when attending to young children, EMS personnel may experience challenges such as high emotional load, anxiety, and uncertainty [12, 15, 16].

Not all patients need EMS transportation to a health-care facility. However, non-transport is not possible in every health-care system, and the concept of non-transport has been under debate [17, 18]. At the same time as demand and expenses for health-care services rise worldwide, the pressure to finding cost-effective solutions is high. Non-transportation offers a reasonable alternative, and EMS comprehensively employ non-transport protocols in Finland. Indeed, around four out of ten patients are not transported in Finland [1, 19]. However, the safety of non-transportation needs to be considered critically, especially in the pediatric population.

The invasion of the COVID-19 pandemic provided an opportunity to study EMS contacts with children under exceptional circumstances. The contacts with health-care facilities for other reasons decreased substantially because the population obeyed social distancing- and self-quarantine recommendations [20, 21]. Similar findings of a decreased number in pediatric patients appeared in reports around the globe [22–26]. At the same time, worried comments about possible collateral damage in children began to emerge [27, 28].

Although interest in EMS contacts with children and publications on this topic appear to have risen lately, only limited research exists on the subject [3, 13, 29–32]. Based on these unsettled questions and identified gaps in the literature, the aim of the present study was to investigate characteristics, outcomes, and risk factors in EMS contacts with children, especially in pediatric seizure patients, infants, and children who were evaluated by EMS but were not transported to any health-care facility. Further, this study explored whether and how the COVID-19 pandemic and restriction measures affected OOH emergencies in a Finnish pediatric population.

2 Literature Review

2.1 Pediatric out-of-hospital emergencies

2.1.1 Children and EMS

Children account for only a small proportion of all EMS contacts, ranging from 4.5% to 15% of patients [1, 3–5, 33]. Different proportions can be partially explained by inconsistent definitions of a pediatric population. In Finland, the pediatric population in health care consists of children under 16 years old [1], the upper age-limit for a pediatric population reported in the studies ranges from 14 to ≤ 21 [34–37]. The Pediatric Emergency Care Applied Research Network (PECARN) defines a pediatric patient as a person $\leq$ 19 years of age [38].

Another explanation for variable proportions of EMS contacts with children is study setting. Some of the studies have explored only subpopulations of pediatric OOH missions such as only those in which a physician is involved [11, 33, 34], only ones dealing with trauma patients [37], or only patients who visit EDs of nonfederal and short-stay hospitals [39].

Differences in dispatch and OOH protocols also exist [3, 40] and may explain, in part, variations in proportion of EMS contacts with children. In this study, the term "pediatric" includes all children under the age of 16, regardless of the reason behind their EMS contact. A short description of studies on pediatric OOH patients is summarized in Table 1.

2.1.2 Organization of EMS

EMS provide health care and transportation in the OOH setting for the acutely sick and injured civilian population. That includes reaching the patient, assessing that patient's health status, performing possible interventions and giving health-care advice, and, if needed, providing transportation to a health-care facility. Some EMS providers also offer interfacility transfer and non-emergency services, but provision of such services is out of the scope of this study.

Organization of EMS varies largely in structure, funding, resource, administration, and work force not only between countries, but also to some degree within the same country [41–44].

The three most common ways to fund EMS are a tax-based system, privately supported serivces, or a hybrid model. Tax-based funding usually occurs at the governmental or municipal level and is the system in some parts of the USA, China, and Europe [43–46]. In the USA, privately supported services are also relatively common [43]. In this system, the cost to a patient is high and usually requires health insurance. In the US hybrid form, where funding comes via public, as well as private channels, some reimbursement is paid

Table 1: Studies on pediatric OOH emergencies

First Author, year, Country, n of ped pts studied	study design	study setting and study period	the amount (%) of ped EMS encounters per year
Europe			
Andersen 2018, Denmark, n = 466	- a retrospective, observational study of pediatric emergency calls to a dispatch center and the medical issues leading to these calls and the units dispatched	- rural and urban areas of Southern Denmark; population 1 210 000 people - 1 month: February 2016	(6.9%) of calls to dispatch center
Magnusson 2018, Sweden, n = 651	- a prospective, observational study on the EMS personnel assessment, level of care and outcomes among children seen by EMS	- urban area, western Sweden, 900 km²; population 660 000 - 12 months in 2016 – first 1 000 each month of all population => 12 000 pt	3 150 (5,4%)
Demaret 2016, Belgium, n = 15 294	- a retrospective, national observational study describing the pediatric physician-staffed EMS missions compared to the adult EMS missions	- Belgium, national data *- population: 10 400 000* *- area: 30 500 km²* - 24 months (Jan 2012 – Dec 2013)	7 647 (6%)
Harve 2016, Finland, n = 1 863	- a prospective, population-based study on pediatric out-of-hospital emergencies	- Helsinki 214 km²; population 603 968; ped population 92 700 - 12 months in 2012	1 863 (4.5%)
Eich 2009, Germany, n = 2 271	- a retrospective study of physician-staffed pediatric OOH emergencies	- Germany, Göttingen, 6 000 km² - population 600 000 - 108 months (Jan 1998 – Dec 2006)	250 (6.3%)
North America			
Oliveira J e. Silva 2019, USA, n = 239 243	- a retrospective observational study of privately insured pediatric patients who was transported by EMS from non-hospital facilities to the ED	- USA - administrative claims data from the OptumLabs Data Warehouse (OLDW): a database composed of privately insured and Medicare beneficiaries - 120 months (Jan 2007 – Dec 2016)	*23 900*
Ramgopal 2018a, Pennsylvania, USA, n = 21 883	- a retrospective review of ground EMS transports from scene to a hospital evaluating assessments in pediatric patients compared to that of adults	- 20 urban, suburban, and rural EMS agencies in Southwestern Pennsylvania - 45 months (Apr 2013 – Dec 2016)	*5 840 (5.9%)*
Ramgopal 2018b, Pennsylvania, USA, n = 30 663	- a retrospective review of ground EMS contacts and risk factors associated with non-transport in pediatric patients	- 24 urban, suburban and rural EMS agencies in Western Pennsylvania - 48 months (Jan 2014 – Dec 2017)	*11 100* (6.4%)
Dayal 2017, California, USA, n = 507	- a retrospective study comparing demographic and clinical features of children who arrived at EDs by EMS to those who arrived by other mode of transportation	- region of rural (and poor) northern California, *18 100 km²*; population: 213 000 - 12 months in 2013	n/a
Diggs, 2016, 41 states in the USA, n = 350 414	- a retrospective descriptive study of pediatric OOH BLS care	- data contained 23 897 211 activations from 41 states - Northeast 40.8%; South 39.7%; Midwest 11.8%; West 7.8% - urban areas 86.3%; suburban areas 6.8%; rural areas 5.4%; wilderness 1.5% - 12 months (Jan 2013 – Dec 2013)	1 761 950 (7.4%)
Drayna 2015, Wisconsin, USA, n = 9 956	- a retrospective cohort analysis concentrating on transported pediatric patients in a large metropolitan EMS system	- Milwaukee County, Wisconsin, *620 km²;* population 1 000 000; ped population 250 000 - 24 months: Oct 2011 – Sept 2013	*- 7 260* (8.7%)
Lerner 2013, 11 states, USA, n = 514 880	- a retrospective analysis of electronic data of pediatric patietns who were transported by PECARN's affiliated EMS agencies	- 12 PECARN's partner EMS agencies operating on ground + 2 HEMS from 11 states - 36 mo (2004-2006)	*total: 171 600* *HEMS: 173*
Shah 2008, USA, n = 7 900 000	- a cross-sectional probability sample survey of pediatric visits to EDs of nonfederal and short-stay hospitals, for which the patient arrived by EMS	- urban 83% Northeast: 22%; Midwest: 27%; South 35%; West 16% - 36 months (1997-2000)	2 630 000 (13%)
Kannikeswaran 2007, Michigan, USA, n = 5 976	- a retrospective analysis of pediatric transports and non-transports in an urban EMS system	- Detroit Fire Department Dicision of EMS - Detroit, population 951 270 - ped population <18 yrs 21% *(200 000)* - 8 months (Jan – Aug 2002)	*8 840* (7,1%)
Haines 2006, Ohio, USA, n = 5 336	- a prospective observational case series of paramedic-initiated non-transport of pediatric patients	Summit County, Ohio rural, suburban and urban areas; population 600 000, <18 yrs 25.4% (152 000) - 6 months (Aug 2003 – Jan 2004)	11 000
Kahalé 2006, Canada, n = 345	- a prospective cohort study of characteristics and outcomes of non-transported pediatric patients	*Ottawa, Canada, 2,757 km²; population 750 000; combined rural and urban* - 5 months (Jan – May 2003)	n/a
Richard 2006, Canada, n = 1 377	- a prospective descriptive cohort study on children transported by EMS	- Ottawa, Canada, 2,757 km²; population 750 000; combined rural and urban - 6 months (Apr – Sept 2001)	*2 750* (4.6%)
Gerlacher 2001, *Texas(?)*, USA, n = 15 409	- a retrospective cross-sectional study incorporated with a nested case-control study on prehospital evaluation of non-transported pediatric patients	- a large urban municipality of *1 550 km²* - population 1.8 million - 12 months (Jul 1996 – Jun 1997)	15 000 *(9.4%)*
Seltzer 2001, California, USA, n = 89	- a retrospective telephone follow-up survey involving parents of minors for whom transport was refused after accessing EMS	urban city of San Diego, 890 km²; population 1.2 million 9 months	n/a
Tsai 1987, California, USA, n = 3 184	- a retrospective study on epidemiology of pediatric OOH care	Fresno County, California, 15,500 *km²;* population 557 000, ped population <19 yo 32% *(16 700)* - 12 mo: Aug 1983 – July 1984	3 184

First Author, year, Country, n of ped pts studied	study design	study setting and study period	the amount (%) of ped EMS encounters per year
Asia			
Lee 2017, South Korea, n = 238 644	- a retrospective study on epidemiology of pediatric patients trans- ported by the National 119 Rescue Services in Korea	- 7 metropolitan cities and 9 provinces metropolitan 42.7%; provincial 57.3% - 36 mo (2006-2008)	79 548 (6,5%)
Australia			
Barker 2014, Australia, n = 349	- a retrospective cohort analysis of pediatric HEMS patients	- Sydney, Australia - 5 y period Apr 2007 – Apr 2012 - working hours only 12h – 09:30 – 21:30	"children represent 15% of caseload"
Africa			
Dworkin 2020, Rwanda, n = 636	- a retrospective, descriptive analysis of injured children managed by EMS	- Kigali, Rwanda - 1.3 million population - 52% of population under the age of 20 - 42 months: Dec 2012 – May 2016	*180 injured children* (10%)

Italics – estimated calculations based on the numbers provided in the article; *% calculated of all patients in the study, unless stated otherwise (not always calculable)*
BLS, Basic Life Support; ED, Emergency Department; EMS, Emergency Medical Services; HEMS, Helicopter Emergency Service; n, number; n/a, not available; OOH, out-of-hospital; PECARN, Pediatric Emergency Care Applied Research Network; ped, pediatric; pts, patients

either to the provider or to the patient [43]. In Australia and Israel, the only statewise EMS provider is defined by law [47, 48]. In some countries, non-profit organizations or other volunteers also participate in providing EMS [43, 48, 49].

The cost of EMS contact with a patient varies substantially. Whereas equity of access is mostly guaranteed by the state for residents in Nordic countries and the UK [44, 46, 50], in the USA and China, "fee for service" usually applies [43, 45]. Typically, health insurance is required in order to cover high costs [43, 45]. The cost of EMS and health care contributes to the threshold for calling an ambulance. If the cost is high, patients or care-givers may hope for a spontaneous recovery and call an ambulance at the very last minute [45]. If the cost is low, no economic restraints impact on the decision of calling an ambulance.

EMS consist of an emergency response center (ERC), which receives emergency calls, and the responding units that include ambulances, fire department and rescue units, and police. Operators working at an ERC, communicate not only with the caller, but also with the units to be dispatched. Adequate resource allocation and risk assessment in dispatching units may be life-saving. Therefore, prompt and rapid evaluation of the situation by phone, when the caller may be in acute distress, requires skill, knowledge, and social proficiency. ERC operators are, however, not always formally trained, and their training is not universal or standardized [43]. Many countries have one single number for all emergencies [43, 44]. Some countries, however, have separate numbers for police, fire department, and ambulance services [45]. For example in China, operators cannot dispatch ambulances by phone, but a call is forwarded to the closest appropriate hospital, wherefrom the actual ambulance service is provided [45].

Typically, the EMS organization is multi-leveled, consisting of first responders, who are able to perform life-saving procedures. Especially in rural areas, volunteers take part in providing emergency care as first responders [43,48,49]. The second level provides more sophisticated care; and the third level comprises usually physician-staffed ambulances or fixed-wing planes or helicopters [43, 44, 47]. In China, there are no paramedics, but nurses, doctors, and drivers are employed in the EMS [45]. At least the UK and New South Wales in Australia use solo responders [47, 50].

The dispatching protocols vary: while some EMS systems have integrated in the protocols that a physician is always dispatched in case of a pediatric emergency [11,49], other EMS systems rely on paramedics providing care according to standard protocols [1,43]. In the latter case, EMS personnel may have an opportunity to consult a physician [1, 43]. Also, the transportation protocols vary. In some countries, all the patients are transported to a health-care facility [4]. In others, non-transportation is allowed [18].

Most countries have no separate pediatric EMS care, but children form a proportion of their EMS contacts, and all units are prepared to provide care for everyone, irrespective of age. Some EMS systems, however, have specially designated pediatric EMS. [43, 48]. Australia's New South Wales Newborn and Pædiatric Emergency Transport Service (NETS) is responsible for medical retrieval of critically ill newborns, infants, and children up to 16 years of age. NETS Retrieval Teams comprise a specialist pediatrician and a nurse. Collaboration and communication between pediatric hospitals, particularly in managing intensive-care resources, is facilitated through NETS [47].

In Finland, health care is publicly funded, and EMS access is, in principal, equally available to all residents. The cost of the EMS evaluation and transport for a patient in 2021 was 16 euros [51]. A single emergency number, "112", is used for all emergencies in European Union countries. A caller activates an emergency chain of care by dialling that number. An ERC operator who answers the phone makes a risk assessment and dispatches appropriate authorities to the scene. The operator assigns a priority code from A to D, where A is the most urgent priority, together with a mission code. The responding unit is thus aware of the character of the upcoming mission, as well as how urgent and critical the situation is on-scene [52]. The organization of the EMS system is described in more detail in Section 4 "Materials and Methods".

2.1.3 Characteristics of children who have EMS contact

Clinical characteristics of pediatric OOH emergencies reflect the age-dependent needs of the pediatric population. Whereas infants tend to have breathing-associated problems, toddlers suffer from (febrile) seizures, traumas affect school-aged children, and mental health causes problems in adolescents [11, 32, 34]. What also seems true is that fewer pediatric trauma cases occur in Europe than in the USA [1, 3, 5, 53].

The age distribution of the pediatric EMS population resembles a U-curve, where extremes at both ends are overrepresented compared to the prevalence of that age group in the pediatric population [1,5,11]. Harve et al. reported the mean age of EMS contact to be 8 years, whereas mean age was 13 years in a study by Oliveira J e. Silva et al. [1,32]. The median age varied from 3 to 6 years [3, 4, 30].

Male patients comprise a slightly higher proportion than female patients 52% versus 59% [1, 3, 4], the highest proportion of 65% being reported for pediatric trauma patients [37].

Studies on a general population have shown that racial and ethnic minorities utilize EMS more frequently than does the white Caucasian population [54, 55]. Indications are that this could also apply to the pediatric EMS population, as Shah et al. demonstrated an association between African-Americans and increased EMS use [39].

Numerous social factors affect the utilization of health-care services in children [56–58]. Studies on socioeconomic factors in EMS contacts with children are, however, scarce. Salmi et al. found a positive association between lower socioeconomic status and incidence of OOH emergencies [59]. Listo et al. showed that traumatic emergencies occur more often in neighborhoods with lower median income per household and are more common in children living in areas with lower education, higher unemployment, and lower median income per inhabitant [60]. Surprisingly, Oliveira J. e Silva et al. [32] report the highest proportion of children with EMS contacts (39%) as living in the highest household income group of $100 000. The reason behind this finding could be that this group studied only privately insured pediatric patients [32]. Children from lower income households may have no access to private insurance. Moreover, Salmi et al. and Listo et al. report EMS contacts from Finland, where EMS care is equally available for everybody and is not dependent on the family's economic status [59, 60]. Thus, the cost of the contact does not affect the decision of whether or not to call an ambulance.

To conclude, numerous medical and non-medical factors such as demographic, geographic, social, and economic, influence pediatric contacts with EMS [35].

2.1.4 Characteristics of pediatric contacts with EMS

Dispatch protocols vary among differing countries and are not comparable as such [3]. Response times depend on the organization of EMS and distance traveled to the patient. In Denmark, an ambulance with an anesthesiologist-manned Mobile Emergency Care Unit (MECU) responds to over half of all pediatric EMS missions. Moreover, missions with priority A comprise a total of 73.4% [3]. In Sweden, a lights and siren response equals 69% of EMS missions [30]. In Finland, only 46.5% of pediatric missions are dispatched with lights and siren, with the top A priority being just 3.5% of all pediatric responses [1]. In the USA, the highest priority response is granted for 56.2 % to 57.9 % of pediatric EMS missions [32, 61]. Especially the dispatching of physician-staffed units appears to depend on the EMS system. In Finland, the unit is dispatched in 4% [1], in Belgium in 15% [11], and in Denmark in 56% of pediatric cases [1, 3, 11].

About one third of patients in the following five studies had contact with the EMS during office hours from 8 to 16 [1, 30, 36, 39, 53]. However, nearly half the patients were treated after office hours, 16 to 24 [1, 30, 36, 39, 53]. Only a small proportion, 13% to 17% is encountered during the night hours, 0 to 8 [1, 30, 36, 39, 53]. When studies have reported a 6-hour time frame, around 70% of the EMS contacts with children occur between 12:00 and 23:59 [1, 4, 31, 36, 53].

Studies show that about 30% of contacts occur during weekends and 70% on weekdays [4,31,37,53]. No significant seasonal variation appears to occur in the EMS contacts with children, but missions are distributed evenly throughout the year. [1, 4, 31, 35].

EMS perform numerous interventions on-scene. Among the most frequent is vital sign monitoring [1, 4, 30]. However, vital signs are less frequently documented in children than in adults [13, 35]. EMS also deliver therapy. Drug administration varies, ranging from 10% to 36% [1, 30, 31, 62, 63] and oxygen administration from 5% to 27% [4, 5, 30–32, 35, 62, 64]. Intravenous (iv) access is established in a small proportion of patients, from 4% to 17% [5, 31, 32, 35, 53, 61–64]. IV access and endotracheal intubation are reportedly less frequently successful in children than in adults [11, 53], so intra-osseus access is more frequent in children than in adults [11]. Advance life support measures are seldom required, and cardiopulmonary resuscitation (CPR) is performed in pediatric populations in 0.12% to 0.7% of cases [4, 35, 61–64]. In a physician-staffed ambulance or helicopter, CPR is performed more frequently, in up to 7% of cases [33, 34]. In a South Korean study by Lee et al. no drugs were administered, and no iv access established even though the CPR rate was 0.6% [4]. In an African study among pediatric trauma patients by Dworkin et al., 70% of patients received pain medication, 34% received iv fluids, and 15% received oxygen therapy [37].

The mean time spent on-scene can range from 12 to 16 min [5, 31, 61]. According to Tsai et al., factors that affect on-scene time include motor-vehicle accidents associated with difficult extrication; and the child's age: the younger the child, the more difficult it is to establish an IV line [53].

Two studies report similar numbers after EMS transport of children to the ED: 83% of children needed ED care, and 16% of them were admitted as inpatients [32, 39]. Kost et al. and Richard et al. report, on the other hand, that only a fraction of high-acuity pediatric patients arrive via ambulance to an ED [5,65]. Shah et al. states that compared to adults, at 18.4%, fewer children (7.1%) are transported to ED by EMS [39].

Reported on-scene mortality for EMS contacts with children ranges from 0.5 to 0.65% [1, 37, 61].

2.1.5 Challenges in pediatric OOH emergency medicine care

Taking care of pediatric patients provokes strong emotions, may be stressful, and may cause anxiety and discomfort to EMS personnel [7, 15, 16, 66, 67]. The following reasons may explain these feelings: first, providers sympathize and identify with children, and they are reluctant to cause pain or see a child hurt [15, 16, 66, 68]. Second, pediatric contacts are few, making exposure to children rare. The resultant lack of expertise leads to extra pressure concerning pediatric contacts [7, 16, 67, 68]. Further, children are anatomically, physiologically and developmentally different from adults, resulting in the need of proficiency in a wide range of weight- and size-based medication and equipment, as well as mastery of many guidelines [7, 67, 68]. Moreover, the fact that children may have minimal symptoms from an injury and then deteriorate rapidly causes constant stress during treatment and transport [7,67,68]. Moreover, communication barriers such as those due to patient age, parental distress, and non-native language play a role [7]. In addition, separating a child from parents and restraining a child to achieve traffic safety may be in conflict with the medical and emotional well-being of a child during transportation [15, 68]. Finally, knowledge that children transported by EMS are more likely to require immediate care and more likely to be admitted to the hospital, is likely to cause distress [7, 39].

The same factors that cause stress and anxiety contribute to patient safety hazards in EMS contacts with children [13, 16, 69]. Unfortunately, as Meckler et al. report, during high-risk OOH care of pediatric patients, untoward patient safety events are common, potentially severe, but largely preventable [12]. Children's Safety Initiative-EMS have ranked clinical assessment to be the number-one factor contributing to patient safety events and errors in the OOH emergency care of children [16]. A lack of familiarity with pediatric patients and equipment, and inadequate practical training and experience in caring for the pediatric population may both lead to significant medication and treatment errors [12, 66].

Problems such as lack of appropriately sized equipment or standardized pediatric medication dosages, insufficient human resources, and unique aspects of EMS culture, should be addressed at systems level [7, 66]. EMS team-level factors should concentrate on improving communication with other EMS providers (both prehospital and hospital) [7]. Family and child factors, including communication barriers and challenging clinical situations or scene characteristics, are hard to control [7]. Provider-level factors such as heightened levels of anxiety, insufficient experience and training with children, and errors in assessment and decision-making, should be recognized and tackled with regular traditional or web-based training [7, 66, 67]. Tools that support reasoning and decision-making during stressful conditions, ones such as cognitive aids, may also help to mitigate anxiety in providing prehospital care of children. [67].

2.2 Pediatric seizure patients and EMS

Seizures are one of the most common reasons for children to be in contact with the health-care services [1, 3, 5]. Indeed, in a study by Alpern et al., the diagnosis of convulsions was associated with the largest proportion of EMS pediatric transport to the emergency department (ED), amounting, among all of the EMS transport, to 9% [38].

2.2.1 Definitions

Seizure

The International League Against Epilepsy (ILAE) and the International Bureau for Epilepsy (IBE) define an epileptic seizure as "a transient occurrence of signs and /or symptoms due to abnormal excessive or synchronous neuronal activity in the brain" [70]. To differentiate an epileptic seizure from any type of severe or acute incident (such as "heart seizure"), authors underline the "epileptic" in the definition. In the present work, a seizure refers to an epileptic seizure, unless otherwise stated.

Epilepsy

ILAE's clinical definition of epilepsy is as follows: "Epilepsy is a disease of the brain defined by any of the following conditions:

1. at least two unprovoked or reflex seizures occurring > 24 h apart
2. one unprovoked or reflex seizure and a probability of having another seizure similar to the general recurrence risk (at least 60%) after two unprovoked seizures, occuring over the next 10 years
3. diagnosis of an epilepsy syndrome" [71, 72]

Epilepsies are classified based on seizure type, epilepsy type, epilepsy syndrome, and etiology [73].

Febrile seizure

Febrile seizures associate with fever, and exclude central nervous system infections, underlying epilepsy, or any another known cause [73, 74]. Febrile seizures are the most common type of seizure in childhood, occurring in 2% to 14% of children from the age of 6 months to 6 years, with incidence depending on genetic background [9, 73]. According to Mikkonen et al., febrile seizures present clear diurnal and seasonal variation, but do not follow the amount of daylight [74].

2.2.2 Clinical characteristics

Seizures can affect autonomic, motor, and sensory functions, and present as sudden changes in awareness, emotional state, cognition, or behavior [70]. Motor symptoms, ones such as repetitive rhythmic jerking of muscles or stiffening or rigidity of all or some parts of the body, are easily visible. Non-motor manifestations such as alterations in vision, taste, smell, or perception, are usually difficult to perceive [73]. Clinical manifestations are, however, less frequently observed in children than in adults, including unconsciousness, pupillary abnormalities, and cardiac arrhythmias [11].

Seizures are common in children and account for 9% to 22% of EMS contacts with children [1, 3, 5, 30, 62, 63]. The age-peak of febrile seizures among children aged 1 to 5 is reflected in the EMS contacts: in that age group, seizures are the most important reason for calling EMS, responding to 24% to 40% of contacts [3, 9, 34, 62, 64].

Harve et al. reported that seizures were the number one reason for dispatch among the most urgent dispatch priority category A in the age group of 4 to 6 years. Furthermore, seizures were the number one dispatch reason in the second most urgent priority category B for the age groups 1 to 3 and 4 to 6 [1]. The data of Richard et al. revealed that EMS contact due to seizures occurred most frequently at home (in 79% of cases), and EMS was summoned to public places in 9.3% and to a school in 7.4% of seizure cases [5].

2.2.3 On-scene interventions and therapy

Status epilepticus is associated with many untoward outcomes such as neurocognitive and developmental impairments and even death [10, 75]. It is therefore essential that each ERC operator or member of EMS personnel be able to recognize seizures, preferably during the emergency call, because prompt termination of seizures is essential to prevent the development of status epilepticus [10, 11]. EMS personnel, however, sometimes have problems with recognition of transient seizures [1]. In a study by Richard et al., 83% of seizures ended before EMS arrival, and 1.9% while EMS personnel were at the scene. In 4.3% of cases, seizure continued en route to the hospital, and a child was still convulsing at the time of ED arrival in 3% of cases [5]. In a Belgian study by Demaret et al., the prevalence of seizures at the arrival of the emergency and resuscitation mobile unit (ERMU) at the scene was higher in children than in adults (11.7% versus 2.4%, $P<0.001$) [11].

Gaínza-Lein et al. have shown that untimely first-line benzodiazepine treatment in pediatric seizure patients was independently associated with use of continuous infusions, with longer convulsion duration, with more frequent hypotension, and even with higher frequency of death [10]. EMS personnel should therefore aggressively treat on-going seizures, while checking and addressing vital signs routinely, because 65% of seized patients did show at least one abnormal vital sign [62]. Because establishing an iv route in children may be challenging [53], other administration routes, including intranasal or buccal, for delivery of anticonvulsive therapy, may be preferable [76].

2.2.4 Outcomes of children suffering seizure

According to Richard et al., even though EMS transported 88% of seized children to a hospital, those discharged home from the ED reached 90% [5]. Only 6% were admitted to the ward and 0.7% admitted to the ICU [5]. Eventually, pediatric seizures were often diagnosed as simple febrile convulsions [77, 78], and the childrens' prognosis was good [9]. However, recurrent febrile seizures or prolonged convulsions may negatively impact a child's development [9, 10, 79].

Seizures are very common in children; they cause concern in families and require considerable resources from the health-care system, both in the OOH and ED setting. Future studies should help EMS personnel to initiate an appropriate treatment for a child with convulsions [11]. In order to accomplish that goal, the chain of care for seizures needs to be considered. ERC operators play an important role in recognition of seizures and in providing first-aid instructions prior to EMS arrival in order to assist callers reporting convulsions [11]. EMS personnel, on the other hand, need training not only in recognition and handling of seizures, but also in early administration of treatment and in alternative routes of medication [1,10,11,34]. When asked, paramedics suggested the following actions to improve pediatric seizure care: dose standardization, equipment availability, protocol clarity, and simplified controlled substance logistics [8].

2.3 EMS contacts with infants

Infants, under the age of one, form a fraction of all EMS contacts, but are overrepresented in the EMS responses [1, 14], comprising up to 15% of EMS contacts with children [3,11,31,63].

Non-specific reasons for EMS involvement such as general medical problem or other or unclear problem or sick child, cause about half of all EMS contacts with infants [3,13,64]. The most usual specific issues include respiratory problems (27%), trauma (11%), and neurological problems (8.6%) (sample size weighted mean) [3,11,13,34,62,63].

Worldwide, differences in organization among EMS are reflected in dispatch priority for infants [3]. Whereas Danish operators defined an A priority category for 84 % of infants and even sent MECU for 79% to the scene [3], Finnish ERC operators dispatched 60% of infant EMS missions in the lights and siren category, with the most urgent priority category A being the choice in only 4% [1]. In Finland, none of the infant EMS missions were dispatched in the least urgent priority D category [1].

Even though infants are prone to potentially severe, and mainly preventable safety events [12], infants and neonates have the smallest odds of complete vital-sign assessment among all EMS patients (pediatric and adult) [13]. The most frequent vital signs measured were heart rate, from 95% to 57%, respiratory rate, from 93% to 81%, and Glascow Coma Scale at around 85% [13,62].

Delivering health care to infants requires special skills and equipment. Establishing an iv connection is highly unsuccessful in infants [53]. Yet, in a study by Demaret et al., physician-staffed EMS established an iv infusion for 46% of infants and administered iv drugs in 10% of cases [11]. EMS personnel need also to be proficient in CPR, intubation, and establishment of intraosseous (io) access, even though these are rare interventions [11, 34]. Noticeably, around half of the pediatric cardiac arrests happen in the infant population [34,53,64]. Indeed, infants comprise 60% of pediatric deaths in the UK [80]. A summary of studies on infants and EMS appears in Table 2.

Not all EMS contacts with infants are emergencies. Rosenberg et al. have reported that 37% of infants could have used alternative transportation instead of EMS [81]. In Finland, the proportion of non-transported infants was as high as 57% [1]. In the USA, on the other hand, non-transportation was less likely for infants (OR 0.52, 95% CI 0.40–0.66) compared to $\geq$12 year-old patients [31].

Table 2: Summary of studies on EMS contacts with infants

First Author, year, Country ped n studied	Study sample characteristics age and sex, % of ped EMS contacts	The reason of contact with EMS	Dispatched prehospital units and transportation	Interventions and therapeutics on-scene	The most important findings in infants
Europe					
Andersen 2018, Denmark, n = 466	*56 infants* 12.0% of ped calls	37.5% sick child 16.1% unclear problem 16.1% ordered mission 12.5% seizures	MECU + A 78.6% A: 5.4% B: 7.1% No ambulance 8.9%		
Demaret 2016, Belgium, n = 15 294	*2 294 infants* 15% of ped patients	40.3% respiratory problems		- iv infusion 45.9% - iv drug 9.8% - attempt of tracheal intubation 4.4% - io access 3.7% - external cardiac compression 3.1% - immobilization 3%	The prevalence of the pediatric diagnoses showed an age dependency: the respiratory problems were more prevalent in infants (40.3 %) than older children
Harve 2016, Finland, n = 1 863	*192 infants* 10.3% of ped patients	The most common complaints according to dispatch category: A – cardiac arrest 1.6% (3/192) B – dyspnoea 15.6% (30/192) C – low energy fall 9.4% (18/192)	A: 3.7% B: 56.3% C: 40.1% D: 0.0% *transported only 43.2%*		
Eich 2009, Germany, n = 2 271	*319 infants* 14.0% of ped patients	- respiratory 34.5% - other diagnoses 32.3% - convulsions 17.2% - trauma 16.0% conditions leading to CPR (24 cases – 7.5%) - SIDS 62.5% (15/24) - aspiration 12.5% (3/24) - arrhythmia 8% (2/24) - convulsion, chest infection, postnatal, unknown each 1/24		- intubation 7.5% - CPR 7.5% - io 2.8% - defibrillation 0.9% - chest drain 0.0%	The leading diagnosis groups were age dependent: 34.5% of infants had respiratory disorders, 17.2% - convulsions, and 16.0% trauma
North America					
Ramgopal 2018a, Pennsylvania, USA, n = 21 883	*2 832 infants* ≤30 days: *1.6%* of ped patients 1 month to < 1 year *11.3%* of ped patients sex: *55.6%* male	- general medical 49.5% - respiratory /airways 22.2% - trauma 10.8% - other 6.8% 0.0% psychiatric /behavioral problems		*- heart rate 94.6%* *- SBP 66.6%* *- respiratory rate 92.7%* *- all 3 vital signs 65.9%* *- pulse oximetry 16.9%* *- lung sound 20.8%* *in resp patients: 76.6% and 93.8%* *- pain score 1.6%* *- GCS 10.6%* *in trauma patients: 15.4% and 98.9%* - monitor placement in 100% of cardiac pts	Neonates and infants had the smaller odds of complete vital signs assessment of all OOH patients (pediatric and adults).
Ramgopal 2018b, Pennsylvania, USA, n = 30 663	*3 894 infants* ≤30 days: 1.9% of ped patients 1 month to < 1 year 10.8% of ped patients		*transported 85.3%* *not transported 14.7%*		Non-transports were less likely for 1 month to 1 year (OR 0.52, 95\% CI 0.40–0.66) compared to patients ≥ 12 years of age
Diggs 2016, 41 states, USA, n = 350 414	19 035 infants 5.4% of ped patients	- possible injury 14.4% - possible cardiac arrest 0.16%			
Drayna 2015 Wisconsin, USA, n = 9 956	1,081 infants *(10.9%)*	- respiratory distress 38.8% - other 21.5% - seizure 7.3% - fever 6.0% - trauma 5.7% - weakness 4.9%		*- GCS 84.5%* *- respiratory rate 81.3%* *- heart rate 57.1%* *- respiratory effort 44.3%* *- pulse oximetry 21.6%* *- SBP 8.0%*	

First Author, year, Country ped n studied	Study sample characteristics age and sex, % of ped EMS contacts	The reason of contact with EMS	Dispatched prehospital units and transportation	Interventions and therapeutics on-scene	The most important findings in infants
Lerner 2013, 11 states, USA, n = 514 880	6 290 infants <1 years *11.3% of ped patients*	- respiratory distress 22.4% - general illness 16.2% - traumatic injury 12.6% - seizure 8.3% - pain non-chest /non-abdomen 7.1% - airway obstruction 5.5% - cardiac arrest 4.0%			
Kannikeswaran 2007, Michigan, USA, n = 5 976	606 infants *(10.1%)*	*medical reasons 85.0%* *trauma 15.0%* *- difficulty in breathing 27.6%* *- other 22.3%* *- fever 19.8%* *- MVA 6.6%* *- fall 3.5%* *- assault 1.8%*			- 10 of 20 children with arrest <1 yo
Richard 2006, Canada, n = 1 377	140 infants (10.2%)				
Gerlacher 2001, *Texas(?)*, USA, n = 15 409	only non-transported analysed by age group 3 057 non-transported ped patients 567 infants (18.5%)	- choking episode 29.6% - injury 10.9% - other 10.2% - febrile illness 10.1%			
Tsai 1987, California, USA, n = 3 184	244 infants (7.7%)	*- medical 82%* *- trauma 18%*		- evaluation 52.4% - BLS 23.3% - ALS 24.2% - iv attempt 5%	- management was significantly different according to age: to infants more ALS than to older children - iv attempt highly unsuccessful (71.4%) in infants
Africa					
Dworkin 2020, Rwanda, n = 636	10 infants (2%)				

Some studies only provide age-related data and do not discuss infants further. *Italics – estimated calculations based on the numbers provided in the article. % calculated of infants in the study, unless stated otherwise.*
abbreviations:
ALS, Advanced Life Support; BLS, Basic Life Support; CI, confidence interval; CPR, Cardiopulmonary resuscitation; GCS, Glascow Coma Scale; ED, Emergency Department; EMS, Emergency Medical Services; im, intramuscular; io, intraosseous; iv, intravenous; MECU, Mobile Emergecny Care Unit; MICU, Mobile Intensive Care Unit; MVA, Motor Vehicle Accident; n, number; OOH, out-of-hospital; OR, odds ratio; ped, pediatric; p.r., per rectum; pts, patients; resp, respiratory; SBP, systolic blood pressure; s.l., sublingual; yo, years old; yrs, years

2.4 Non-transportation in EMS contacts with children

Studies on non-transported children are few, and each study reports findings in its own manner. The terminology is unestablished, and results between studies are sometimes contradictory.

Camasso-Richardson et al. raised the topic of EMS being misused as a taxi service for the pediatric population already in the late 90s [82]. Studies report from 28% to 61% of pediatric EMS transportation being inappropriate [81–83]. On the other hand, studies also report that only 13% to 20% of high-acuity pediatric patients arrive via ambulance [65,84], and 38% to 40% of pediatric trauma patients arrive at trauma centers by non-EMS transport [85, 86]. Moreover, adult patients utilize EMS transport more often than do child patients for both routine and emergency complaints [87]. The balance between over- and underutilization the EMS is clearly undetermined.

The transportation itself, especially use of lights and siren, exposes pediatric patients to superfluous traffic hazards [88–90]. Moreover, EMS personnel seldom transport infants correctly in an ambulance; family cars usually possess safer equipment for child transportation [89].

2.4.1 Definitions

According to Ebben et al., [18] The NHS Litigation Authority (2012) defines transportation as "the transfer of patients, medical and clinical personnel, equipment and associated records, as appropriate including from one health-care facility to another as well as the initial journey from the scene." Non-transportation was defined as "an ambulance deployment as appropriate, where the patient after examination and / or treatment on-scene does not require conveyance with medical personnel and equipment to the health-care facility." Non-transported patients can be treated and "discharged" on-scene, or may be referred to other health-care facilities such as a general practitioner. Non-transportation can be divided into two categories: patient-initiated refusal and an EMS personnel professional decision [91]. In some parts of the USA and other countries, the EMS organization has not supported provider-initiated non-transport [4, 17, 31, 92]. However, two studies from Northern Europe reported EMS-initiated non-transport of children, in which the decision was based on EMS personnel-independent professional evaluation and a possibility of physician consultation by phone or by asking for additional resources on-scene [1, 30].

2.4.2 Reasons for non-transport

In Finland and Sweden, EMS personnel may conclude either that transportation with an ambulance is unnecessary or that no further immediate health-care professional evaluation is required. Before EMS personnel decide against transporting a patient, they have to adequately assess the patient, document the reasons behind the decision, and provide instructions on when to contact the health-care services or to call for help [1,30]. In this study, non-transported patients are further divided into those who do need no ambulance transportation, but with a health-care contact recommended, and those needing no further health-care contact at the time of EMS contact. For the reasons behind non-transport see Table 5.

2.4.3 Characteristics of pediatric non-transport patients

The pediatric non-transportation rate has ranged from 0% in Asia [4], 10% in Africa [37], 13% to 31% in North America [5,36,53,62,64], to 30% to 40% in Northern Europe [1,30].

Age distribution in the non-transported pediatric population appears to depend on the local EMS system. The mean ranges from 3.7 to 8 years [31, 36, 92–94], and Magnusson et al. report median age to be as low as 2 years [30]. It seems that in the USA, non-transported patients are older than in Europe. Indeed, Ramgopal et al. report that the younger the patient, the lower are the odds for non-transportation [31]. Kannikeswaran et al. notice non-transport to occur more likely for adolescents [64].

According to Magnusson et al., previous medical conditions such as asthma, congenital disability, febrile non-epileptic convulsions and allergies do not appear to have any effect on the non-transportation rate of children [30].

The dispatch category of non-transported children is less acute than that of those transported [30]. Response time ranges from 8 to 9 minutes [31, 64]. The on-scene time range extends from 20 to 24 min [31, 64], and is significantly longer in non-transported children [64].

No conclusions can be drawn about time of occurence of non-transport. Magnusson et al. report more non-transport to occur during the night hours from 24:00 to 8:00 and less during office hours from 8:00 to 16:00 [30]. According to Ramgopal et al., however, the odds ratio for non-transport was higher all day compared to the times 00:00 to 05:59 [31]. Moreover, Gerlacher et al. report non-transport to be uncommon in the early morning hours [93]. When speaking about seasonal variation, according to Ramgopal et al., non-transport is less likely to occur in winter than in fall [31].

In one study from Europe, more non-transported children were assessed to have respiratory difficulties and fever, and less to be suffering from trauma and convulsions [30]. In the USA, on the other hand, trauma patients constituted almost half of the non-transport category [31, 64, 93]. Kannikeswaran et al. reported non-transports more likely to have been involved in assaults [64]. The following conditions and proportions emerge among non-transported patients: trauma (25% to 51%), motor vehicle accidents (25%), respiratory difficulties (11% to 25%), fever (18%), general medical condition (14%) [30, 31, 64, 93, 94].

The assessment of non-transported children is less often systematic. Harve et al. reported that no vital signs were measured in 16% of non-transported patients compared to 13% in those transported [1]. Ramgopal et al. [31] reported at least one vital sign to be assessed in only 58% of non-transported patients compared to 84% in transported children. When Harve et al. evaluated EMS patient records retrospectively, they assessed OOH care to be inadequate in only nine non-transported cases (1%) [1]. The explanation behind this finding may be that non-transported children were acutely less ill. In fact, if the document sheet provides no field for observations such as first impression, the observation is not documented, even if EMS personnel did make mental notes on the appearance of the child. In addition, EMS personnel performed significantly fewer interventions involving non-transported children than for those transported [30].

2.4.4 Outcomes of children not transported by EMS

Up to half of non-transported children had secondary contact with health-care services within the following 72 hours [1, 36, 91, 92]. The majority of these contacts (77% to 89%) were expected or intended; i.e. the EMS personnel instructed family to contact the ED or a pediatric clinic [1, 91]. Of non-transported children, 1% to 5% were admitted to the hospital [36, 91, 92], but ICU admissions tend to be rare among non-transported children [36,91]. Studies have found no associations between mortality and non-transport [1, 36, 91, 92].

Overall, non-transported patients or their parents or both appear to be satisfied with the care provided by EMS. When asked about satisfaction with EMS care on a five-point Likert scale, the median satisfaction figure was 5 [36].

2.5 COVID-19 and EMS contacts with children

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes the infectious disease (COVID-19). After the first report of novel coronavirus from Wuhan, China, in late November 2019, it rapidly spread across the globe, causing a pandemic, and health care and economic catastrophe [95].

2.5.1 SARS-CoV-2 virus

SARS-CoV-2 is a member of the *Coronaviridae* virus group. It is a round virus containing a single-stranded, positive-sense RNA genome surrounded by an extracellular membrane containing a series of spike glycoproteins resembling a crown, thus the name (latin corona - crown) [96]. Coronaviruses are able to infect a variety of hosts and cross species barriers. Those coronaviruses that infect the upper respiratory tract cause mild symptoms. However, others are able to infect the lower respiratory tract system, causing severe diseases including SARS-CoV (severe acute respiratory syndrome), MERS-CoV (Middle East respiratory syndrome), and SARS-CoV-2 (COVID-19) [96].

2.5.2 Pathophysiology and clinical features

The severity of COVID-19 infection depends on factors such as individual genetics, ethnicity, age, and geographic location [96]. In severe cases, COVID-19 pathophysiology includes destruction of lung epithelial cells, thrombosis, hypercoagulation, and vascular leak leading to sepsis. These events result in acute respiratory distress syndrome (ARDS) and subsequent pulmonary fibrosis [96]. The risk factors for severe COVID-19 infection include high age, obesity, cardiovascular disease, hypertension, diabetes, and respiratory disease. [96–98].

2.5.2.1 COVID-19 in the pediatric population

Only limited data regarding the pediatric demographics and clinical features of COVID-19 disease exist thus far.

Attack rates indicate children to be as susceptible to COVID-19 infection as are adults [95]. Children appear to be less affected than adults because their symptoms are usually milder; they may even remain asymptomatic [95,99]. Symptoms are usually mild and non-specific such as fever (38% to 64%), cough (35% to 48%), sore throat (28.6%), and upper respiratory tract symptoms (13.7% to 35%). 5% to 15% of patients remain asymptomatic [95, 99–101]. Gastrointestinal symptoms such as diarrhea and vomiting /nausea also occur in 7.7% to 10.1% [99,101]. Lower respiratory symptoms affect only a small proportion of patients (5.1%) [101].

It seems that COVID-19 affects males more often than females (56% to 65%) [99, 101]. Infants are more at risk for COVID-19 infection than are older children. For one under-5-year-old population, half the infections appeared in infants [101]. Moreover, infants comprised 27% of children hospitalized due to COVID-19 infection [99]. Other pediatric risk groups included children with asthma or cardiovascular disease or who were immunosuppressed [99].

The reported number of severe cases among pediatric populations diagnosed with COVID-19 has ranged from 2.5% to 7.6% [95,100,101]. The mortality due to COVID-19 in pediatric populations ranges between 0.016% to 0.2% [95, 96, 100, 101].

2.5.3 Restrictions to curb the pandemic

The World Health Organization declared a pandemic on 11 March 2020 [102], with many countries implementing unprecedented restriction measures to protect their residents.

In Finland, restrictions followed one after another. On March 15, the Finnish Government limited public social gatherings to a maximum of 500 participants, and the next day, the Government announced a state of emergency. On 18 March, national restrictions with social distancing were launched and schools closed. On 19 March, strict national border control came into force. Finally, isolation of Uusimaa - the population-richest region of Finland - was issued on 28 March. As the situation with pandemic improved somewhat, the isolation of Uusimaa was canceled on 15 April, and schools reopened on 14 May. The timeline of COVID-19 pandemic invasion is depicted in Figure 1. Even stricter restriction measures such as total lockdowns, have occured in some countries [103–105]. On the other hand, Sweden had a more relaxed approach to the pandemic, aiming at herd immunity of the population with fewer restrictions [106].

The Finnish Government adopted a resolution on a plan for a hybrid strategy to manage the COVID-19 crisis on 6 May. This hybrid strategy means moving from extensive restrictions on society towards a testing, tracing, isolation, and treatment approach, while at the same time, certain restrictions remain in place, and the effects of pandemic control measures are closely monitored [109, 110].

2.5.4 Effects of restriction measures on EMS contacts with children

Restrictions designed to curb the pandemic have affected pediatric populations in many ways worldwide. First, EMS responses and pediatric ED visits have experienced dramatic drops [24, 27, 111, 112]. Reallocation of resources and abrupt changes in health-care delivery have generally resulted in a reduction in non-urgent pediatric receptions and in outpatient clinic visits [24].

Emergency health-care systems themselves have changed: in EDs and prehospital EMS, patient flows have slowed, partly due to infection-control measures, including the use of personal protective equipment and meticulous cleaning; and modified treatment protocols have been developed. On the other hand, the omnipresence of COVID-19 in the news and media may have created a bias in clinicians, predisposing them to diagnostic errors such as suspecting COVID-19 infections in children rather than more common conditions [113].

Moreover, the everyday life of children has changed dramatically. Social distancing and closing of schools has resulted in decreased contacts with friends and adults. The International Society for Social Pediatrics and Child Health (ISSOP) claims that restriction measures of the pandemic have compromised several Rights articulated in the United Nations Convention on the Rights of the Child [114].

Health-care professionals have expressed concern over children as becoming second victims of the pandemic [27, 28, 111]. Whereas the pandemic itself has, for the most part, spared children from severe COVID-19 disease manifestations, the restrictions designed to curb the pandemic may be harmful to children in several ways. The European Academy of Paediatrics (EAP) has asked European leaders and national governments to take urgent action to mitigate the impact that COVID is having on the health and well-being of children, now and for many years to come. [115].

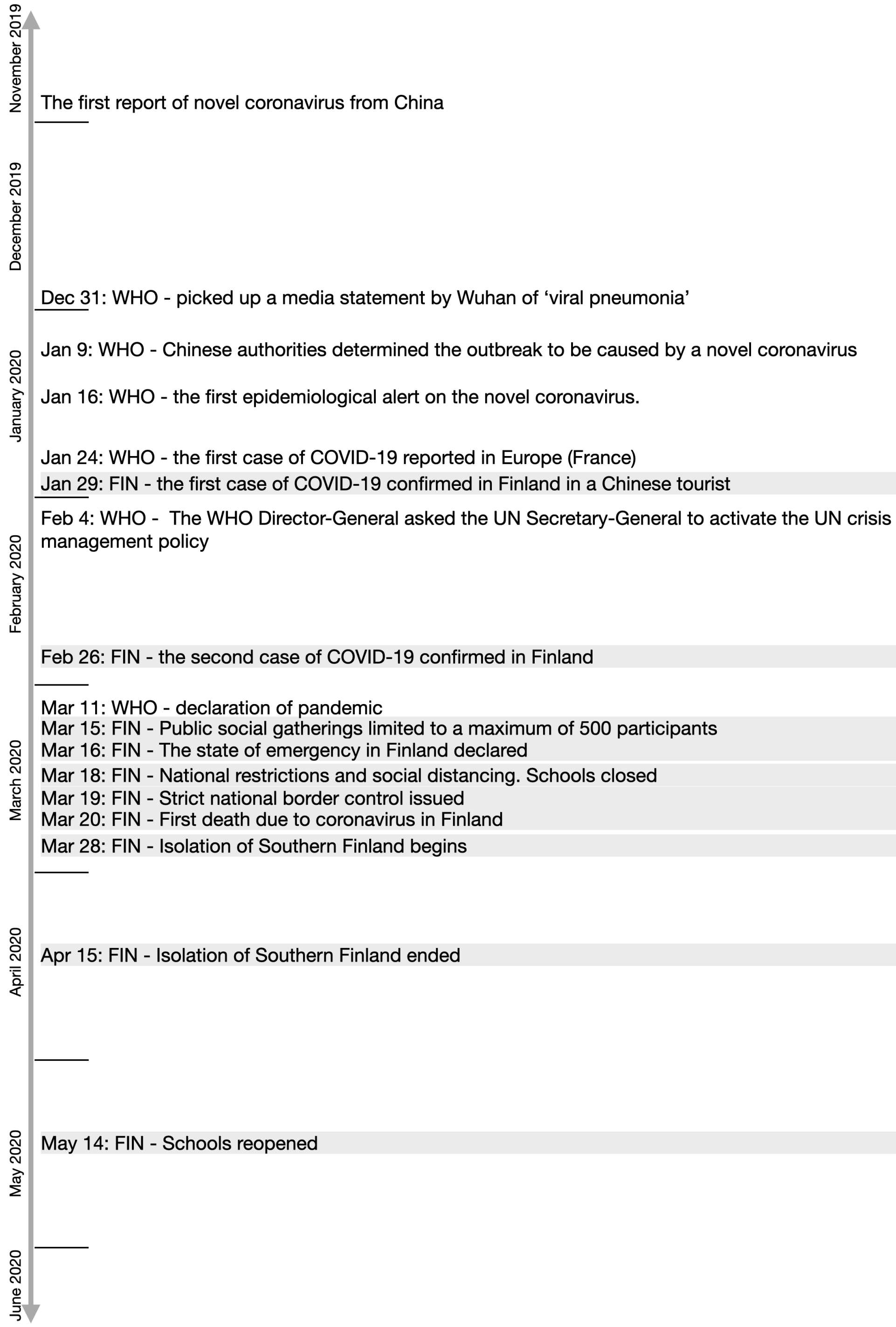

Figure 1: Timeline of the first wave of COVID-19 pandemic and protection measures. Adapted from https://fi.wikipedia.org/wiki/Suomen_koronaviruspandemian_aikajana, accessed 22 May 2021 and https://en.wikipedia.org/wiki/Timeline_of_the_COVID-19_pandemic, accessed 22 May 2021. [107, 108]

3 Study Questions

This study aimed to investigate pediatric OOH care in the Helsinki University Hospital (HUH) area, focusing specifically on following objectives:

1. What are the characteristics and outcomes of EMS contacts with children in three various subpopulations: pediatric-seizure patients, infants, and children who are evaluated, but not transported by ambulance?
2. Do identifiable risk factors exist for secondary outcomes in EMS contacts with children?
3. Whether the COVID-19 pandemic and resultant restrictions designed to curb the pandemic have impacted OOH emergencies in the pediatric population during the first wave, and how?

4 Methods

4.1 Study Design

This research includes four register-based retrospective cohort studies focusing on EMS contacts with children from various perspectives. The study population comprised children under 16 years old who had had contact with EMS in the study area during the study period, except for Study III, in which the study population comprised 0- to 11-month-old infants (Table 3). The focus of the first study is on children who were evaluated by EMS personnel, but not transported by ambulance to any health-care facility (I). The second study discusses seizures in children in an OOH setting (II). The third study concentrates on infants (III), while the fourth study examines pediatric OOH emergencies and restrictions during the first wave of the COVID-19 pandemic (IV).

Table 3: An overview of study design and setting in this dissertation

	Study I	Study II	Study III	Study IV
Study design	retrospective cohort study on non-transportation in EMS contacts with children	retrospective cohort study of EMS contacts due to seizures in children	retrospective cohort study of EMS contacts with infants	retrospective cohort study of EMS contacts with children during the first wave of COVID-19
Study population and area	<16-year-old children in Helsinki	<16-year-old children in Helsinki	<1-year-old children in Helsinki	<16-year-old children in Espoo, Helsinki, Kauniainen, Kerava, Kirkkonummi, and Vantaa
Study Period	3 years: 1 Jan 2014–31 Dec 2016	1 year: 1 Jan 2012–31 Dec 2012	5 years 1 Jan 2013 – 31 Dec 2017	3 months: Study:1Mar 2020-31May 2020 Cohort: 1 Mar 2019-31 May 2019, 1 Mar 2018-31 May 2018, 1 Mar 2017-31 May 2017
Basic statistics about the population in the area	2015 population: 628 208 <16 years: 93 054	2012 population: 603 968 <16 years: 92 742	2017 population: 643 000 <1 year: 6 548	2020 population: 1 274 000 <16 years: 218 000

4.2 Study Setting

4.2.1 Definitions

Pediatric population

In this study, the term ”pediatric” includes all children under the age of 16, regardless of the reason behind their contact with EMS. In other words, no separation exists between surgical and other pediatric patients.

Interfacility transfer and non-emergency services

Interfacility transfer and non-emergency services are beyond the scope of this study, although some EMS providers also offer such services.

P and Q diagnoses

In the International Classification of Diseases-10 (ICD-10), diagnoses within the P category represent conditions related to prematurity or problems during the neonatal period, and those in the Q category represent congenital malformations, deformations, and chromosomal abnormalities [116].

4.2.2 Finnish health care and social security system

Finland is a Nordic welfare state with a publicly financed universal health-care system, supplemented by private or government-subsidized health-care providers. Municipalities run the system, provide primary and secondary health care, and jointly fund tertiary care in five university hospitals. Private-care providers offer some primary and secondary care.

Every Finnish citizen and every person permanently living in Finland has a unique personal identification number. Moreover, every Finnish resident is also entitled to full social security, including health-care services and costs, the latter two covered minus a deductible fee.

Visiting free public prenatal clinics for pregnant women is a prerequisite for getting the baby box and maternity leave. After a child is born, a family is directed to attend a well-baby clinic, which takes care of children aged 0 to 6 years. Prenatal and well-baby clinics offer parent training, and all families may contact their own community health nurse with problems and questions concerning child health-care or growth-related issues. Further follow-up of a child's well-being and development takes place in school. In Finland, compulsory education is required for children under the age of 17. Thus, advice and health care for infants and children are, in principle, easily available regardless of a family's socioeconomic status.

The public health-care system exclusively provides all OOH emergency care, including emergency call dispatching and emergency transportation. The care is provided for all acutely ill or injured patients irrespective of citizenship, social insurance, or the lack of a personal identification number.

4.2.3 Study area

These studies were conducted in Helsinki (I-III) and the Helsinki University Hospital (HUH) area (IV). In addition to Helsinki, the HUH area includes the surrounding municipalities of Espoo, Kauniainen, Kerava, Kirkkonummi, and Vantaa. At the end of 2020, the HUH area comprised 1.27 million people, including 218 000 0 to 15 years old [117]. Helsinki is the capital and the largest city of Finland (population 657 000; its 0- to 15-year-old population was 99 600 and <1-year-old population 6 500 in 2020) [117]. The area comprises urban, suburban, and rural environments.

4.3 Organization of EMS

4.3.1 EMS

A single EMS system covers the HUH area, and its electronic patient-record system (EPRS) (MerlotMedi®, CGI Suomi Oy) forms a population-based database on all OOH treatment. In Helsinki, the ambulance personnel work 12 hours shifts, 09:00–21:00 or 21:00–9:00 and doctors are on duty 24 hours per shift. Outside Helsinki, the duration of the ambulance personnel working shifts varies from 8 to 24 hours.

The EMS in Finland is three-tiered. The first tier consists of basic life-support (BLS) units and the second tier of advanced life-support (ALS) units. The BLS units are staffed by emergency-medicine technicians (EMT). In the ALS units, at least one person is a paramedic. In the HUH area are also three medical supervisor units staffed by experienced paramedics with advanced training. One of the supervisor units is based in Helsinki. An emergency medical physician, together with two or three paramedics or EMTs comprise a third tier, also called a mobile intensive-care unit (MICU). The HUH area has two physician-staffed units on duty 24/7, one based on a ground ambulance serving the Helsinki area, and another based on a helicopter, serving larger metropolitan and Uusimaa regions.

Governmental legislation regulates the education level of emergency medicine (EM) personnel. These personnel are trained to make decisions independently. However, they have the possibility of consultation with a physician by phone, via EPRS, or they may even call additional units, including a physician, to the scene. The electronic EMS patient-record system has an integrated consultation tool with the possibility for instance of e.g. sending photographs.

4.3.2 Dispatch system

All OOH emergency calls in Helsinki and the HUH area are dispatched through the same number, 112, and the same governmental Emergency Response Center (ERC).

A professional ERC operator evaluates emergency calls according to a protocol that is sensitive, but not very specific [118]. An operator first categorizes the leading complaint to formulate a symptom-based mission code and then determines a priority category from A to D based on risk assessment (Table 4). Operators only evaluate the symptoms and their possible risks for the patient's health; they do not make diagnoses. In fact, operators are rarely health-care professionals. They have formal 18-months training to become an ERC operator, instead.

If an ambulance is needed, it is dispatched with the combination of a symptom-based mission code and a priority category. The same set of symptom codes and priority categories are used for all patients regardless of age. In the case of a pediatric patient,

Table 4: Dispatch priority definitions.

Dispatch priority codes	A	B	C	D
Definition	High risk /unstable patient	Moderate or unclear risk for imminent failure of vital functions	Low risk or minor symptoms	No risk or stable vital functions
Dispatch or transport priority	Immediate dispatch with lights and siren	Immediate dispatch with lights and siren	Patient reached within 30 min; normal driving	Patient reached within 120 min; normal driving

min = minutes

Adapted from Harve et al. (2016), Hoikka et al. (2016), and Kuisma et al. (2013) [1, 52, 118].

the formulation of the questionnaire protocol is also the same, except for some additional questions.

If the emergency call does not concern an emergency, the dispatch protocol may suggest not dispatching an ambulance, but advising the patient or the parents instead.

4.3.3 Transportation and non-transportation

After adequate examination and treatment, the EMS personnel decide on the leading cause for transportation and appropriate priority category A to D (Table 4).

In Finland, EMS do not transport all encountered patients to health-care facilities. In the case that ambulance transport is not needed, the EM personnel must inform the patient and / or the caregivers how to monitor and treat the symptoms, and must give instructions on whether and when they should visit health-care services or call again for help.

The EMS personnel then document the non-transport decision and the reasoning behind this decision in the EPRS. Non-transport decisions are classified in the X priority category. The Finnish non-transportation classification system is presented in Table 5.

The cost of the EMS evaluation and transport to the patient in 2020 was 16 euros and is comparable to the cost of a very short taxi ride. EMS do not require payment or health insurance prior to delivering treatment or transporting. Thus, all children have equal access to EMS in case of emergency, regardless of the family's socioeconomic status.

4.3.4 HUH

HUH provides all pediatric OOH emergency care, pediatric secondary and tertiary ED care, and manages the only pediatric intensive-care unit (PICU) in the study area.

Public-sector and private-care providers offer some primary-level health care for children. Children with an altered medical condition or requiring ambulance transport for medical reasons (or both), however, are referred to HUH pediatric EDs.

Table 5: Non-transportation codes and their significance.

	Explanation	Significance in the study population
X-2 **police**	After evaluation, no need for transport, treatment, or follow-up detectable. Patient escorted to police custody.	Rare in children.
X-3 **other help**	After evaluation, no need for transport, treatment or follow-up detectable, but other help such as social services, indicated.	Rare in children. Typically, social service is called if the parents are incapable of taking care of their child, or when the parents are unreachable.
X-4 **other transport suitable**	After evaluation, an ED visit deemed necessary, but no need for monitoring or ambulance transport.	Common. Typically, caregivers transport a child to ED after minor trauma.
X-5 **no transport needed**	After evaluation, no need for transport, treatment or follow-up detectable.	Common. No immediate health-care services needed. Patient and /or caregivers are advised to contact primary health care during office hours, if problem continues.
X-6 **refusal**	Patient or caregivers refuse treatment and/or transportation.	Rare in children. Not used if the child is judged unable of understanding the risks and taking care of her/ himself. Caregivers not allowed to deny treatment or transport if this has been evaluated as necessary by health-care professionals.
X-8 **treated on-scene**	The patient treated on-scene by ambulance personnel. No need for an ED visit.	Uncommon. Typically used after out-of-hospital treatment of hypoglycemia in a known diabetic patient.

ED, Emergency Department

Adapted from Study I, reprinted with the publisher's permission.

4.4 Data Collection

The study population, study setting, and data collection periods are described above and in Table 3. All studies were register-based retrospective cohort studies. The data because of emergency care centralization, covered all ambulance responses with children in the study population.

Based on a study by Harve et al., we expected mortality in our pediatric population to be low [1]. That is why, in addition to mortality after the EMS contact, we also studied the following secondary outcomes: PICU admission (I-III), hospitalization (I-III), medical state of the child on presentation to ED (I, III), medication or respiratory support given at the ED (III), surgical procedures (III), ED visits of non-transported patients (I-III), unintended ED contacts of non-transported patients (I-III).

We extracted the following variables from OOH EPRS for each of the studies: age, sex, time and reason for contact, dispatch and transport priority, reason for transportation or non-transportation, physiological measurements documented and interventions performed. Additionally, the following variables were recorded: consultation with physician (I, III, IV), native language (IV), additional help requested on-scene (IV), whether COVID-19 was suspected (IV).

In-hospital data were extracted from the HUH in-hospital EPRS (Uranus®, CGI Suomi Oy) for Studies I to III. In addition to Uranus®, we also used Apotti (Epic Systems Corporation) for Study IV. The following variables deserved study and came from in-hospital EPRS: whether any contact was made with ED after non-transportation (I-III), medical state at presentation to ED (I, III), laboratory diagnostics (II,IV), treatments (I-III), surgical procedures (III), diagnoses (I-III), hospitalization (I-III), PICU admissions (I-III), and death (I-IV). Medical condition was judged based on the first documented physiologic measurements or a documented evaluation by the physician or both; and allowed categorization of a normal presentation as "good," and any abnormal measurement or presentation as "other than good" (I,III). If the patient's medical condition was not explicitly stated to be good on arrival at the ED, two experienced pediatricians reviewed the records separately (I).

Demographic data originated in Statistics Finland [117].

4.5 Data Analyses

Statistical analyses were performed with R versions 3.4.4 - 3.6.312 [119], whichever was the latest version at the time. Ggplot2 package [120] visualized the analyses and charted risk plots using the locally estimated scatterplot smoothing (LOESS) method (I, III). The time-of-day variation and seasonal distribution were analyzed visually (III). We used line plots with date as the X-axis to visualize the changes in the infection control measures and our parameters (IV).

Continuous variables, estimates, and proportions were presented as the median and the interquartile range (IQR) (II-IV). Continuous variables were tested using the Mann-Whitney U test (I-IV). Categorical variables were presented as counts, frequencies, and percentages (%) (II-IV). The following tests were performed for categorical variables: χ^2 test (I, II), Fisher's test(III) and Wilcoxon signed-rank test (IV). A P value below 0.05 was considered statistically significant in Studies II and IV, whereas two-tailed P values with a P below 0.05 were considered significant in Studies I and III.

4.6 Ethical aspects

The study was retrospective and register-based, so that no informed consent was required from patients or their caregivers. The study affected neither patient treatment nor were patients contacted for study purposes. The institutional review board of HUH approved the study protocols (University of Helsinki and Helsinki University Hospital; §10 11.11.2015 (I, III); §232 (II), §24 (IV)).

5 Results

5.1 Characteristics and outcomes of EMS contacts with children

5.1.1 Characteristics of EMS contacts with children

The annual incidence of EMS contacts with children per 1 000 <16-year-old-inhabitants fluctuated between 20.5 and 27.8. Among all EMS encounters, the proportion of contacts made with children ranged from 3.9% to 4.8%. For EMS contacts, see Table 6.

Table 6: Frequency of EMS contacts with children

	Study I	Study II	Study III	Study IV
Study period	3 years	1 year	5 years	3 months
all EMS contacts during the study period	199,498	n/a	401,372	28,680
EMS contacts with children during the study period	7765 (3.9%)	1897	n/a	1368 (4.8%)
Incidence of EMS contacts with children*	4.1	3.1	n/a	n/a
Incidence of EMS contacts with children in pediatric population**	27.8	20.5	n/a	n/a

* per 1000 inhabitants per year

** per 1000 <16-year-inhabitant per year

The study involved slightly more boys (52.3-55%) than girls. The median age (IQR) for EMS contact was 6.7 (2.8-9.5) months in infants; 3 (1-7) years in children with seizures; 3.95 (8.74) years in non-transported patients; 7 (2-14) among the pediatric population.

The use of lights and siren during dispatch priority categories A or B ranged from 32.2% in the non-transported pediatric population to 73.3% in the pediatric seizure population. Dyspnea and low-energy falls were among the top three dispatch codes in infants and non-transported pediatric patients. Documentation of vital signs was not systematic. Body temperature was the most documented variable and was measured in 92.8% of pediatric seizure patients. No measurements were conducted in 15% of infants. The EMS personnel used the option of phone consultation with a physician in 11.9% to 15.5% of cases. The transportation rate was 57.1% in the unselected pediatric population and ranged from 39.9% in infants to 73.3% in pediatric seizure patients (Table 7).

The EMS contacts with children happened most frequently in the afternoon or during the evening. The median time (IQR) of EMS contact for those patients evaluated but not transported and with no further contact with ED, was 18:50 (14:41-22:44); and for those who had an unintended visit, 21:32 (17:04-01:37), p<0.001. Some 45% of the contacts with infants occured at 14:00 to 22:00 and peaked around 20:00.

Table 7: Characteristics of EMS contacts with study population

Characteristics of EMS contacts with…	General pediatric population (II)	Non-transported pediatric patients (I)	Pediatric seizure patients (II)	Infants (III)
number of EMS contacts	1 897	3 579	251	1 710
Dispatch priority (%)	A – 66 (3.5) B – 811 (43.6) C – 978 (52.5) D – 7 (0.4)	A – 70 (2.0) B – 1 082 (30.2) C – 2 193 (61.3) D – 234 (6.5)	A – 13 (5.2) B – 171 (68.1) C – 67 (26.7) D – 0 (0)	A – 55 (3.2) B – 789 (46.1) C – 820 (48.0) D – 46 (2.7)
Top 3 dispatch codes (%)	n/a	1. low-energy fall 683 (19.1) 2. dyspnea 553 (15.5) 3. sudden deterioration of general condition 287 (8.0)	n/a	1. dyspnea 471 (27.5) 2. low-energy fall 322 (18.8) 3. choking 144 (8.2)
OOH measurements and interventions (%)	- any medication administered 202 (10.8) - io or iv access 150 (8.1) - intubation 7 (0.4)	n/a	- temperature 233 (92.8) - SpO_2 173 (69) - blood glucose 145 (57.8) - GCS documented in 83 (33.1) - any medication 75 (29.9) - resp rate 38 (15.1) - io or iv access 30 (12) - intubation 2 (0.8)	- no measurements 256 (15.0) - heart rate 1 007 (58.9) - temp measured 994 (58.1) - SpO2 957 (56.0) - resp rate 577 (33.7) - lung auscultation 561 (32.8) - GCS 498 (29.1) - blood pressure 445 (26.0) - blood glucose 343 (20.1) - iv access 2 (0.1)
Transported (%)	1 084 (57.1)	4 173 (53.7)*	184 (73.3)	683 (39.9)
Transport priority (%)	A – 30 (3.2) B – 85 (9.1) C – 689 (73.6) D – 132 (14.1)	n/a	A – 9 (4.9) B – 24 (13.0) C – 139 (75.5) D – 12 (6.5)	n/a

* n of all pediatric contacts during study period was 7 765

gray = values not published

GCS, Glasgow Coma Scale; EMS, Emergency Medical Services; io, intraosseous; iv, intravenous; n/a, not available; OOH, Out-of-hospital; resp, respiratory; SpO_2, peripheral oxygen saturation; temp, temperature

5.1.2 Outcomes of EMS contacts with children

Of all the children who had earlier had contact with EMS, 61.8% visited an ED (Table 8). The proportion who visited an ED after EMS contact ranged between 51.2% in infants to 87.6% in pediatric seizure patients. Over half (53.7%) of the non-transported pediatric seizure patients visited an ED following their EMS contact, whereas the proportions for infants and the unselected pediatric population were a respective 18.9% and 17.4%. The number of unintended visits after the EMS contact was 4.5% for the seizure population, 7.1% for the unselected pediatric population, and 10.3% for infants. Medical state was documented to be other than good for 10.4% (91) of infants visiting the ED; 87.9% of them were transported by ambulance and 12.1% by other means of transport. The proportion of "medical state other than good" -documentation after EMS non-transportation was 1.1% in infants and 0.4% in the unselected pediatric population.

Of the pediatric seizure patients seen at an ED, 2.7% (6) were still seizing upon ED arrival, and 10.9% (24) suffered a new seizure. In addition to those 13.6% (30) of children

Table 8: Outcomes of EMS contacts with study population

Study population outcomes	Non-transported pediatric patients (I)	Pediatric seizure patients (II)	Infants (III)
Total ED visits	4 795 (61.8*)	220 (87.6**)	877 (51.2***)
Non-transported (NT) patients (%)	3 579 (46.1*)	67 (26.7**)	1 027 (60.1***)
ED visits of NT patients (%)	622 (17.4†)	36 (53.7†)	194 (18.9†)
unscheduled ED visits of NT patients (%)	253 (7.1†)	3 (4.5†)	106 (10.3†)
medical condition upon arrival to ED other than good (%)	15 (0.4†)	n/a	91 (10.4‡)
hospitalization (%)	105 (2.9†)	68 (30.9‡)	336 (38.3‡)
PICU admission (%)	2 (0.06†)	2 (0.9‡)	28 (3.2‡)
on-scene mortality (%)	8 (0.1*)	0 (0**)	2 (0.1***)
mortality during the follow-up period[1] (%)	1 (0.03†)	4 (1.6**)	1(0.06***)

* proportion of all pediatric EMS contacts

** proportion of pediatric seizure patients

*** proportion of infant patients

† proportion of NT patients in study population

‡ proportion of ED visits in study population

[1] the Follow-up period 24 months in seizure patients and 12 months in other patients

ED, Emergency Department; n/a, not available; NT, non-transported; PICU, Pediatric Intensive-Care Unit

who already had iv access, it was established in 13.2% (29). ED personnel administered anticonvulsive medication to 14.5% (32) of patients. Despite the medication, one patient (0.4%) developed status epilepticus. Some of the pediatric seizure patients required further investigation: cerebrospinal fluid inspection 6.8% (15), neuroimaging 5% (11), and electroencephalography 4.1% (9). In 70.5% (155) of pediatric seizure patients, new anticonvulsive medication was initiated or previous treatment adjusted. Patients received the following diagnoses: 44.1% (97) had febrile seizures, 2.3% (5) had a serious bacterial infection, but none had bacterial meningitis. The total of 89.5% (197) of patients were left with a diagnosis of non-specific seizure. Of the seizure patients who had ED contact, those with previously diagnosed epilepsy constituted 29.1% (64). Three patients were responsible for almost 10% of all EMS pediatric-seizure contacts.

Of those patients who had an ED visit after an EMS contact, about one-third of the visits (30.9% for seizure patients and 38.3% for infants) ended as beeing hospitalized. A small proportion of these children required PICU care: 3.2% (28) of infants and 0.9% (2) of children with seizure. The number of hospitalizations was significantly lower in those infants not transported by ambulance than that of transported infants: 51 (5.0%) vs 285 (41.7%), $P<0.01$. Hospitalizations in the non-transported pediatric population amounted to 105 (2.9%). The infants not transported by ambulance had fewer PICU admissions than transported infants did: 2 (0.2%) vs. 26 (3.8%), but the comparison failed to reach statistically significance ($P<0.06$). The number of PICU admissions in non-transported pediatric patients was 2 (0.06%).

5.2 Identifiable risk factors for secondary outcomes in EMS contacts with children

Table 9: Associations of various variables and outcomes in infants

Factors associated with MORE unscheduled ED visits in non-transported ped population	Factors associated with medical state other than good in infants	Factors associated with MORE medication or respiratory support in infants	Factors associated with MORE hospitalizations in infants	Factors associated with MORE surgical procedures in infants	Factors associated with MORE PICU admissions in infants
- dyspnea* - vomiting /diarrhea* - mental illness* - younger age - late evening (around 22:00) - night shift	- dyspnea* - seizure* - previous P- or Q-dg	- dyspnea* - seizure* - allergic reaction* - older infants - night time	- dyspnea* - seizure* - urgent dispatch before symptom-specific code known* - previous P- or Q-dg - younger infants - night /evening	- choking* - previous EMS contact within 72 hours - older infants - afternoon	- dyspnea* - urgent dispatch before symptom-specific code known* - previous EMS contact within 72 hours - previous P-dg - younger infants
Factors associated with FEWER unscheduled ED visits in non-transported ped population	Factors associated with GOOD medical state in infants at ED arrival	Factors associated with LESS medication or respiratory support in infants	Factors associated with FEWER hospitalization in infants	Factors associated with FEWER surgical procedure in infants	Factors associated with FEWER PICU admission in infants
- low-energy fall* - allergic reaction*	- low-energy fall* - choking* - no measurements conducted by EMS	- low-energy fall* - choking* - no measurements conducted by EMS	- low-energy fall* - choking* - slow deterioration of medical state* - no measurements conducted by EMS	- dyspnea* - low-energy fall*	- low-energy fall*

* dispatch code
dg, diagnosis; ED, Emergency Department; EMS, Emergency Medical Services

Young age was a risk factor for an unintended ED visit after an EMS contact (2.98 years (IQR 1.04-7.92) vs. 4.18 years (IQR 1.47-10.62), P=0.001) in non-transported children; whereas in infants it was associated with greater risk for PICU admissions (1.79 months (IQR 0.74–8.88) vs. 6.73 months (IQR 2.97–9.48), P<0.01) and hospitalizations (3.49 months (IQR 1.30–8.17) vs. 7.10 months (IQR 3.97–9.63), P<0.001) (Table 9). Older infants were more likely to require medication or respiratory support at ED (7.57 months (IQR 4.25–10.22) vs. 6.43 months (IQR 2.53–9.30), P<0.01) and surgical procedures (9.75 months (IQR 8.75–10.82) vs. 6.63 months (IQR 2.8–9.43), P<0.01). Such associations are in Figure 2.

Dispatch codes "dyspnea" (OR 1.73; 95% CI 1.25-2.36; P<0.001), "vomiting/diarrhea" (OR 2.06; 95% CI 1.07-3.67; P=0.03) and "mental illness" (OR 2.34; 95% CI 1.14-4.40; P<0.02) were risk factors for an unintended ED contact in non-transported children. In infants, the dispatch code "dyspnea" was associated with more PICU admissions (39.3% vs. 27.3%, P=0.02), medical state upon arrival at ED other than good (42.9% vs. 26.7%, P<0.01), any medication or respiratory support given at ED (38.3% vs. 24.3%, P<0.01), hospitalizations (36.3% vs. 25.3%, P<0.01), but fewer surgical procedures (5.6% vs. 27.7%, P=0.03). The dispatch code "urgent dispatch before symptom-specific code known" was associated with more PICU admission (21.4% vs. 5.0%, P<0.01) and more hospitalization (11.6% vs. 3.7%, P<0.01) in infants. Moreover, in infants the dis-

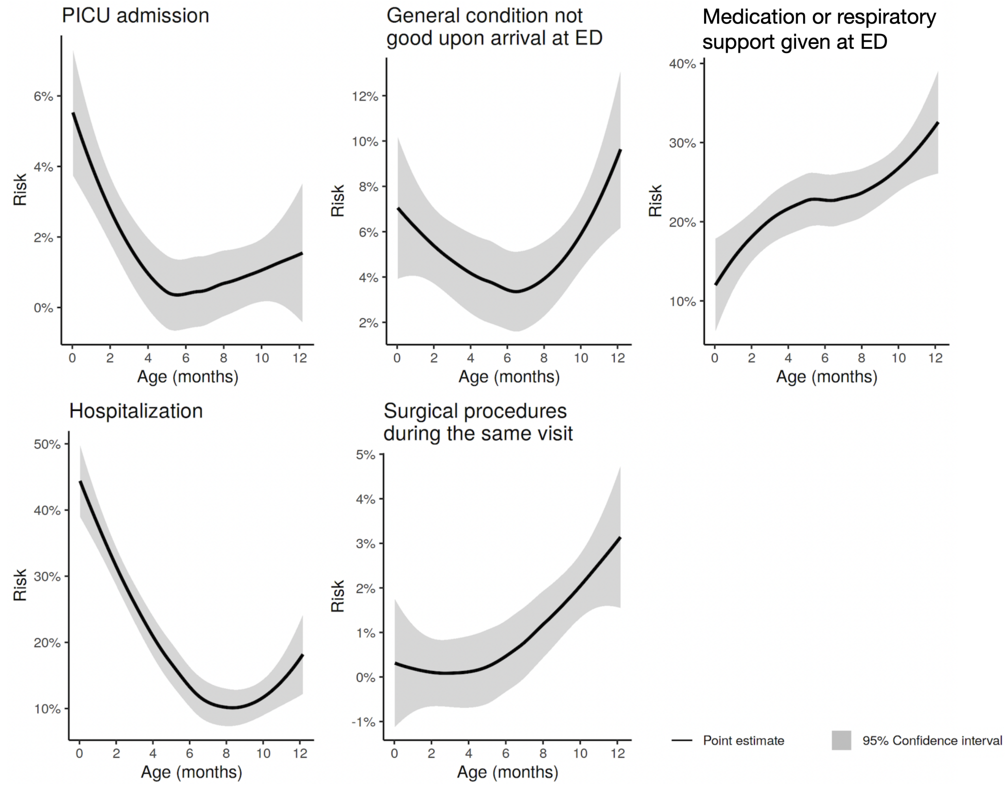

Figure 2: Association of age with secondary outcomes in infants.
Figure from Study III, reprinted with the publisher's permission.

patch code "seizure" was associated with medical state other than good upon arrival at the ED (15.4% vs. 6.4%, P<0.01), with medication or respiratory support at the ED (13.2% vs. 5.0%, P<0.01), and with hospitalization (14.0% vs. 5.1%, P<0.01).

On the other hand, the dispatch code "low-energy fall" was associated in non-transported children with fewer unintended visits (OR 0.43; 95% CI 0.27-0.64; P<0.001), and, in infants with fewer PICU admississions (0.0% vs. 19.0%, P=0.01), good medical state upon arrival at the ED (4.4% vs. 19.6%, P<0.01), less medication or respiratory support at the ED (6.2% vs. 22.4%, P<0.01), less hospitalization (6.8% vs. 21.6%, P<0.01), and fewer surgical procedures (0.0% vs. 18.9%, P=0.03).

The dispatch code "allergic reaction" was associated, in infants, with a lower risk for an unintended ED visit after non-transportation (OR 0.38; 95% CI 0.13-0.85; P<0.05), but with a higher need for medication or respiratory support at ED (7.5% vs. 3.2%, P<0.01). Infants with the dispatch code "choking" had a better medical state upon arrival at the ED (1.1% vs. 8.8%, P<0.01), needed less medication or respiratory support at the ED (1.3% vs. 10.6%, P<0.01), and less hospitalization (3.3% vs. 9.8%, P<0.01). However, they needed more surgical procedures (38.9% vs. 8.1%, P<0.01).

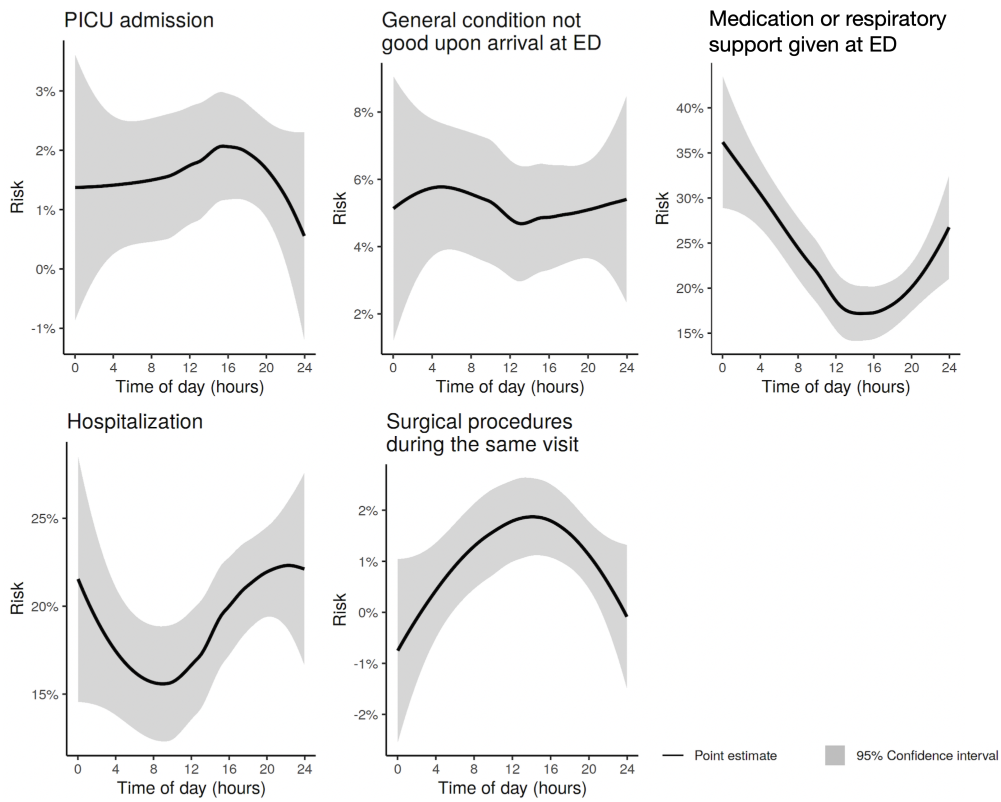

Figure 3: Association of time of EMS contact with secondary outcomes in infants.
Figure from Study III, reprinted with the publisher's permission.

Nightshift (OR 2.13; 95% CI 1.64-2.76; P<0.001) and the time of the EMS contact around 21.53 (OR 1.07; 95% CI 1.05-1.10; P<0.001) were risk factors for an unintended ED visit after non-transportation in the pediatric population. (Figure 3).

In this study, infants with a previous ICD-10-diagnosis within the Q-category were more likely to have medical state other than good upon arrival at an ED (19.8% vs. 5.7%, P<0.01) and more often they needed hospitalization (11.0% vs. 5.4%, P<0.01). In addition to these outcomes, P-category diagnoses were also associated with PICU admission ((25.3% vs. 5.4%, P=0.02), (22.9% vs. 14.3%, P<0.01) and (35.7% vs. 15.7%, P=0.01)).

Infants with previous EMS contact within 72 hours had more PICU admissions (7.1% vs. 1.0%, P=0.04), but fewer surgical procedures (0.0% vs. 1.1%, P<0.05). Infants without any measurements performed OOH more likely were in good medical condition upon ED arrival (4.4% vs. 15.7%, P<0.01), needed less medication or respiratory support (8.5% vs. 16.6%, P<0.01), and required less hospitalization (9.5% vs. 16.1%, P<0.01).

5.3 COVID-19 and EMS contacts with children

During the study period (1 March 2020-31 May 2020), a total of 28 680 prehospital EMS contacts were registered, of which 1 368 (4.8%) concerned children. A reduction of 23.7% occurred in EMS contacts with children during the study period compared with the mean of 1 794 contacts during the control periods (Figure 4). For a timeline of the pandemic versus the number of weekly EMS contacts with children see Figure 5.

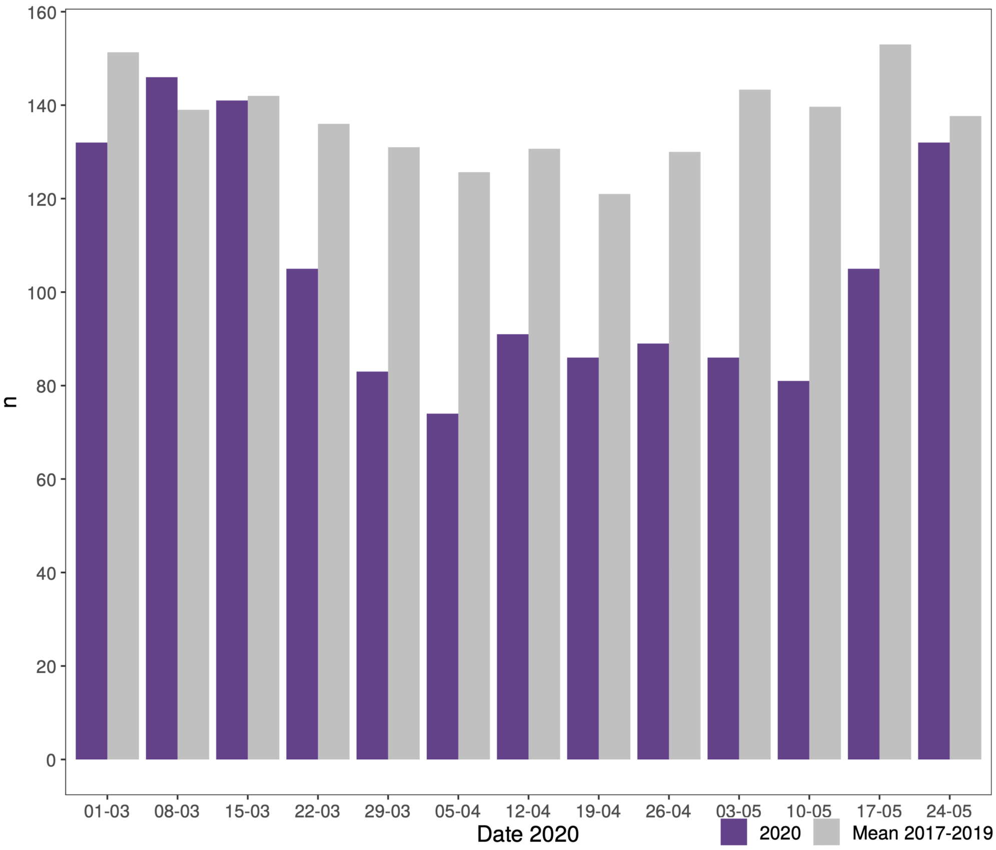

Figure 4: Number of weekly EMS contacts in 2020 with the mean of equivalent periods, 2017-2019.
Figure from Study IV, reprinted with the publisher's permission.

Patients were younger (5.3 years compared with 6.3 ($P<0.001$)) during the first wave of the COVID-19 pandemic, with gender distribution nearly identical in both periods (males 54.0% vs 55.1%).

The absolute number of contacts with the highest dispatch priority A rose from 3.7 contacts per week to 8.0 (+90.9%, $P<0.05$) (Table 10). Moreover, the proportion of the highest priority A dispatch contacts and proportion of the highest priority A transportation were higher in the study period (+139.9%, $P<0.001$ versus +107.2%,

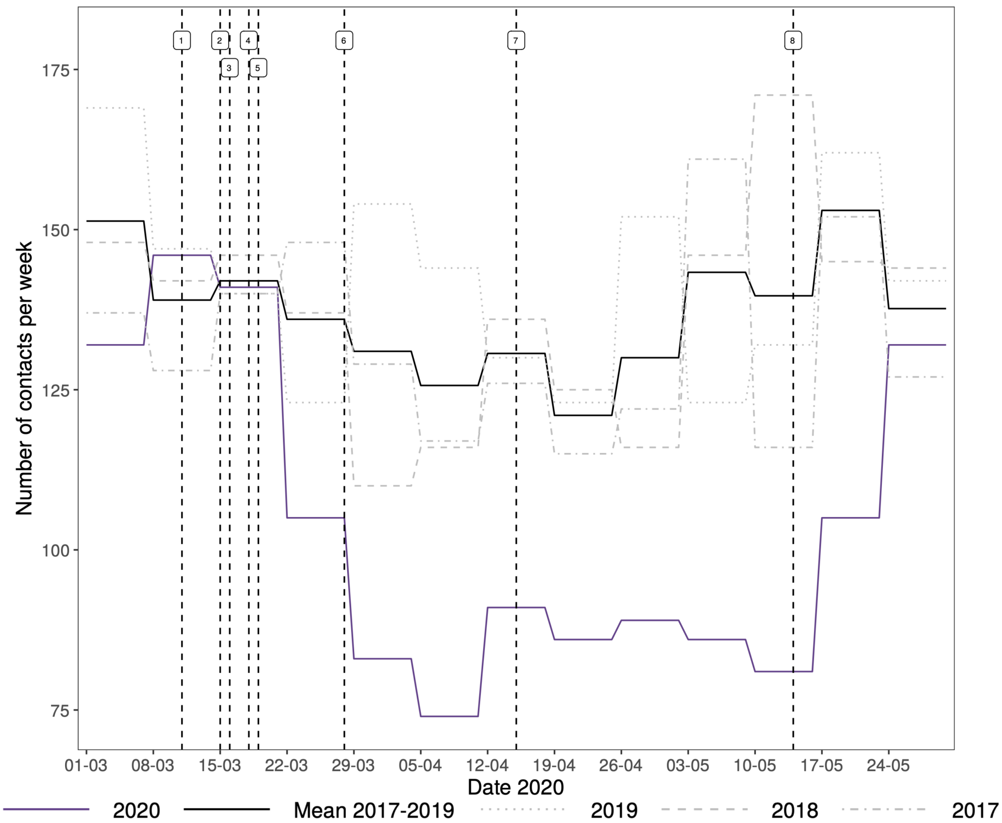

Figure 5: Timeline of course of the first pandemic wave and number of weekly EMS contacts. 1. WHO declared the pandemic on 11 March. 2. Public social gatherings limited to a maximum 500 participants, 15 March. 3. Governmental announcement of a state of emergency, 16 March. 4. National restrictions and social distancing. Schools closed, 18 March. 5. Launch of strict national border control, 19 March. 6. Isolation of southern Finland begun, 28, March. 7. Isolation of southern Finland ended, 15 April. 8. Schools reopened, 14 May.
Figure from Study IV, reprinted with the publisher's permission.

P<0.05). Moreover, the MICU and additional help were more frequently requested on-scene (+46.3%, P<0.05 and +43.3%, P<0.05, respectively).

The proportion of trauma patients increased by 23.7% (P<0.05), despite a reduction in their absolute number of minus 11.9% (P<0.02). The weekly proportion of non-transported patients increased from 47.8% to 58.1% (P<0.001). There emerged no changes in the proportion of vital-sign documentation OOH (-0.0%, P=0.46), but proportion of OOH interventions decreased: supplementary oxygen delivery -19.3% (P=0.74), establishment of iv connection -32.5% (P<0.01), and administration of any medication -35.5% (P<0.02).

Table 10: Change in the dispatch and transportation priority A and additional units requested.

		Mean 2017-2019	2020	Change as percentages	P value
All EMS contacts	all n (%)	1 794 (100.0%)	1 368 (100.0%)		
	n per week median (IQR)	137.7 (130.7 - 142.0)	91.0 (86.0 - 132.0)	-30.4 (-36.6 - -12.8)	**0,003**
Dispatch priority A*	all n (%)	55.3 (3.1%)	90 (6.6%)		
	n per week median (IQR)	3.7 (3.3 - 3.7)	8.0 (7.0 - 8.0)	90.9 (36.4 - 140.0)	**0,031**
	% per week median (IQR)	2.7% (2.4% - 2.8%)	6.1% (5.7% - 8.4%)	139.9 (116.7 - 175.9)	**0,001**
Transportation priority A*	all n (%)	12.3 (0.7%)	6 (0.4%)		
	n per week median (IQR)	1.0 (0.8 - 1.0)	1.0 (1.0 - 1.0)	50.0 (0.0 - 50.0)	0,174
	% per week median (IQR)	0.7% (0.5% - 0.8%)	1.2% (0.9% - 1.2%)	107.2 (52.4 - 381.5)	**0,031**
additional help requested	all n (%)	86.7 (4.8%)	94 (6.9%)		
	n per week median (IQR)	6.3 (5.3 - 7.7)	7.0 (5.0 - 9.0)	23.5 (-29.4 - 31.3)	0,529
	% per week median (IQR)	4.6% (4.0% - 5.6%)	6.8% (4.5% - 8.5%)	43.3 (0.7 - 117.7)	**0,040**
MICU on-scene	all n (%)	26.0 (1.4%)	24 (1.8%)		
	n per week median (IQR)	1.7 (1.3 - 2.3)	2.0 (2.0 - 2.8)	0.0 (-13.2 - 50.0)	0,435
	% per week median (IQR)	1.3% (0.9% - 1.7%)	2.3% (1.4% - 2.5%)	46.3 (-1.4 - 100.5)	**0,049**

EMS, Emergency Medical Services; IQR, Interquartile Range; MICU, mobile intensive care unit

Adapted from Study IV, reprinted with the publisher's permission.

EMS arrived to find four children already dead or found them on-scene during the study period compared to none to two during equivalent periods of the three preceding years (Table 11).

Table 11: Mortality presented by year during equivalent periods of 1 March to 31 May.

	2017	2018	2019	2020	P value
All EMS contacts with children (n)	1 722	1 801	1 857	1 364	
Dead at EMS arrival or on-scene	2	0	1	4	0.060

EMS, Emergency Medical Services

Table from Study IV, reprinted with the publisher's permission.

Of 1 368 children encountered, EMS personnel suspected infection in 103 (7.5%). Of these, four were known to be positive for SARS-CoV-2 at the time of EMS contact, and two new infections were discovered at the ED. EMS personnel did not suspect COVID-19 infection in 1 261 contacts with children, and 41 of these children were tested for COVID-19 at the ED, with one positive result.

6 Discussion

6.1 Summary of the main findings

EMS contacts with children were infrequent, the proportion ranging, in the OOH setting, from 3.9% to 4.8%. About half the missions were dispatched with the lights and siren priority, but the lights and siren were much less frequent during transport, in less than 18% of missions. In children, dispatching in the most urgent A priority category was significantly more frequent during the first wave of the COVID-19 pandemic. The EMS contacts with children due to seizure occurred in 13% of cases, and infants comprised about 0.4% of all EMS contacts.

The OOH documentation of vital signs in pediatric patients could be improved. In children, a complete set of vital parameters was rarely evident. No measurements were conducted in 15% of infants and OOH interventions were rarely necessary. An EMS contact with a child occurred more probably post-meridiem, after office hours.

The non-transportation rate was high in our study and ranged from 26.7% in seizure patients to 60.1% in infants. Untoward events after non-transportation were rare, and hospitalization or PICU admission seldom required. On-scene mortality was very low in children.

Young age was a risk factor for several untoward events such as an unintended ED visit after non-transportation or hospitalization or a PICU admission. The dispatch code "dyspnea" was associated with an unintended ED visit after non-transportation in our pediatric population, as were hospitalization and PICU admission in infants. On the other hand, the dispatch code "low-energy fall" was associated with fewer unintended ED visits after non-transportation in children; like the fewer PICU admissions and better medical state upon arrival to the ED among the infants.

The number of EMS contacts with children dropped during the first wave of the COVID-19 pandemic, but children appeared to be more ill, and the proportion of dispatch and transportation in the most urgent priority A category rose dramatically. Moreover, on-scene mortality in children was higher during the pandemic, although the significance level was not reached due to the rarity of death in our pediatric population. COVID-19 infection among children who experienced EMS contact was rare.

6.2 Relation of results to those of other studies

In this study, the proportion of EMS contacts with children out of all EMS contacts was among the lowest reported so far, ranging from 3.9% to 4.8% [1, 3–5, 33].

The finding that boys had slightly more contacts with EMS is in line with previous findings [1,3,4]. The median age of children with EMS contact in the unselected pediatric population in this study ranged from 6.3 years to 7, which is a little older than the median age in other studies [3, 4, 30].

The use of lights and siren varied between subpopulations of EMS pediatric contacts. The highest proportion of the most urgent priority A category was dispatched in 5.2% of pediatric seizure patients but in only 2.0% of EMS contacts with those pediatric patients eventually not transported. The higher proportion of priority A missions seems reasonable, because seizure patients need prompt treatment that can terminate the seizure and prevent development of status epilepticus [11]. On the other hand, it also seems sensible that those children who do not need ambulance transport are less seriously ill, making priority A dispatch less frequently necessary. The priority A category was dispatched in 3.2% of infants and in 3.5% of an unselected pediatric population, numbers much lower than in reports from other Scandinavian countries [3, 30]. This discrepancy has been attributed to differences in EMS organization and in dispatch protocols [1, 3, 118].

Unfortunately, the documentation of vital signs was not systematic, which is also in line with other studies [13, 62]. Various reasons exist for EMS personnel challenges in assessing and evaluating a child and documenting the condition. First of all, EMS contacts with children are infrequent [1, 7, 67]. Second, vital-sign values are age-dependent, and interpreting them may be difficult, if one is unfamiliar with normal variation [7, 67, 68]. In addition, proper pediatric equipment may not always be available [7, 121]. Furthermore, children are not always cooperative; obtaining reliable vital signs when a child is crying and protesting, is simply impossible. Finally, various psychological factors arise in situations in which EMS personnel attend to children [15, 66].

Clearly, establishing the routine of obtaining a full set of vital signs in children offers an opportunity for training and organizational development. Indeed, reports on successful implementation of training programs have appeared, although the most efficient educational intervention remains to be identified [67, 121]. It is not normal for a child to remain quiet or unresponsive, and one could argue that only then vital signs are necessary. However, taking a full set of vital signs from every child provides an opportunity to practice measurement and interpretation in healthy children. This will build expertise and establish routines, so that evaluating acutely a sick child can then be accomplished without hesitation and in less time.

Non-transportation in a pediatric EMS population is complex, topic full of contradictions. On the one hand potential exists for better resource allocation and addressing the ever-growing demand for health-care services including OOH EMS care [1, 18, 122]. Unjustified ambulance transport, moreover, exposes children to traffic hazards, when family cars are better equipped for child transport [88, 89]. On the other hand, absence of non-transportation protocols or fear of litigation hinders non-transportation [31,36,64]. Non-transportation rate in our pediatric population was high, 46.1%. However, it is comparable to the 44% previously reported from Helsinki [1], and also in line with the 41.7% of non-transportation rate in a general population reported from northern Finland [19].

The non-transportation rate was exceptionally high in our infant population (60.1%) and during the first wave of the COVID-19 pandemic (58.1%). This finding is unexpected and may appear worrying. One might think that in light of the fact that infants are more vulnerable and susceptible to rapid disease progression due to their smaller reserve of compensatory mechanisms, the EMS personnel would be more prone to expedite transportation of that patient group, just for the sake of safety. Moreover, the rise in the non-transportation rate was registered during the COVID-19 pandemic, when the implication arose that children who had contact with EMS, were sicker. This may suggest that a proportion of the contacts in the pediatric population are due to reasons other than acute health problems; they may in fact represent social challenges. The low rate of untoward secondary events supports this assumption. The findings that infants without any OOH measurements probably were in good medical condition upon ED arrival, needed less medication or respiratory support, and did not require hospitalization are suggestive of non-medical reasons for EMS contact. Another explanation could be that EMS is used as a feasible and easily accessible acute mobile health-care and advisory unit, when other services are hard to reach or are unavailable.

In light of adverse outcomes, non-transportation appears to be safe in children and infants. There was no serious deterioration in medical condition, intensive-care admission, or death traceable to non-transport decision. Nonetheless, we identified several factors associated with unintended ED visits, medical condition other than good upon ED arrival, hospitalization, and PICU admission in non-transported children.

Seizures were common among the pediatric population. Substantial resources were allocated both OOH and in-hospital to this subpopulation, because seizure patients required more urgent dispatch and transportation, more treatment, transportation, screening, hospitalization, and follow-up visits than did an unselected pediatric population. EMS organization plays a critical role in identifying patients, medicating seizures, and referring children for further care and investigations. To our knowledge, the finding that not only children with febrile seizures, but also children with poorly controlled epilepsy and recurrent seizures comprise a considerable proportion of EMS contacts with pediatric seizure patients, has not been reported earlier.

The reduction in EMS contacts with children during the first wave of the COVID-19 pandemic was in line with the reports of a decrease in pediatric health-care contacts around the world [26, 123]. Our results show the low rate of EMS contacts with children due to COVID-19 infections during the first wave of the pandemic. However, children whose contact with EMS occurred, were, on average, acutely more ill and required more additional help such as MICU or other extra units. Based on these findings, we agree with those reports concerning children's well-being and with those concerned about children becoming second victims of the COVID-19 pandemic and measures to curb its effects [28, 114, 124–126].

6.3 Study strengths and limitations

This study has several limitations. First and foremost, all studies were register-based and represented a single center. However, because the single EMS system covers the HUH area, its EPRS forms a population-based database. Thus, the study included all EMS contacts with children during the study periods. Moreover, we were able to collect population-based data across several years. In addition, our follow-up period was quite lengthy, ranging from one to two years. Due to the retrospective character of our studies, we could detect only associations and not causalities.

Second, the prevalence of all EMS contacts with children, that is, 112 calls concerning children, could not be estimated, because the study included only those contacts that were dispatched, omitting those without any ambulance response.

Third, we had no access to patient records in primary health care or from private providers. Notwithstanding, all children requiring hospitalization, surgical procedures, or tertiary care would have been referred to pediatric EDs of the HUH.

Finally, children form only a small proportion of all EMS contacts, and in high-income countries, mortality and PICU admission rates are low. We were therefore unable to estimate the incidence of outcomes for power analysis or to draw definitive conclusions about mortality. However, we tried to control confounding factors by extending the study periods from one to five years (I-III) or by studying the control periods from the three preceding years (IV).

Despite these limitations, the strengths of this study also include bringing the important and infrequently studied topic of pediatric EMS contacts into focus. This study covered population-based EMS contacts with an unselected pediatric population, covered pediatric seizure patients, and covered non-transported pediatric patients. This study is also among the first to explore the COVID-19 pandemic invasion and the impact of restrictions on EMS contacts with children.

6.4 Generalizability and clinical implications

The organization of EMS varies widely across the world and the results of this study may only be generalizable only to areas with closely similar circumstances.

Even though children form a small proportion of all EMS contacts, the psychological impacts on EMS personnel relating to these contacts play a huge role [15, 127]. The current study identified several factors that can be taken into account when personnel are in contact with children.

EMS personnel rarely evaluate the child's condition thoroughly. However, EMS personnel should consider any contact with a child as an opportunity to rigorously assess a child's condition and to practice interaction with the child and his/her parents. By applying systematic approach in less urgent situations, routines become established, and less hesitation will result when a true emergency takes place.

The subgroups of seizure and of infant patients constitute distinctive subgroups in the EMS contacts with children. Familiarization with special needs of these groups and developing policies and standards of practice for them could ease anxiety and facilitate development of expertise. We identified several factors associated with untoward outcomes in children such as the dispatch code "dyspnea" in the non-transported pediatric population and for infants, and any earlier diagnosis in the P- or Q-category of ICD-10 diagnoses. Addressing such factors in training or acknowledging their existence could, for instance, aid in the decision of whether or not to transport a child to the ED. For those children with active epilepsy, the plan of emergency management of convulsions should be elaborated in cooperation with pediatricians and neurologists. Considering that rapid cessation of seizures is vital, and establishment of any iv connection difficult [11, 53], EMS personnel should be encouraged to administer timely benzodiazepines via alternative routes.

The figures for non-transportation rate and its safety are similar in other parts of Finland and in Finland's adult population [19, 128]. The safety, in our study, of non-transport decisions appears to be good. However, non-transport strongly depends on the capabilities and training of the ambulance personnel, on the accessibility of other health services, the social and economic factors of the family in question, and the availability of other resources [18, 19, 128]. Although our findings may not necessarily be applicable to other EMS systems as such, they may encourage other EMS systems to evaluate existing non-transport protocols or to pilot new protocols with the possibility of personnel-initiated non-transport. The high non-transportation rate that we identified suggests that the role of EMS is changing, tending toward feasible and accessible mobile health-care and advisory units [128].

Children are infected by the SARS-CoV-2 virus as easily as are adults [95, 129]. However, their symptoms are milder and recovery faster [95, 99]. Therefore, the finding of the present study that children were acutely more ill during the restriction measures of the COVID-19 pandemic is worrisome and needs further elucidation. We hope that policy makers take into account these findings when considering new restrictions to curb future unexpected pathogen outbreaks. Children should not become collaterally damaged by measures set up to protect the society. For example, campaigns focused on reaching children and their parents and reminding them that it is okay to contact health-care services also if feeling unwell for reasons other than the cause of the pandemic. Moreover, if it becomes clear that, overall, children are less affected and recover faster, measures restricting children's everyday-lives should be applied only as the last and final measure for the shortest possible time and also be the first abolished.

6.5 Suggestions for future studies

This study created several further questions for future investigations. First, since EMS contacts with children were rare, multi-center studies could elucidate outcomes of the contacts in other pediatric subgroups, such as dyspnea patients. They could also show whether deciding not to transport pediatric patients to EDs is safe also in dispersed settlement areas.

We could say nothing concerning the prevalence of EMS contacts, because we investigated only dispatched contacts. By studying 112 phone calls, we could explore reasons for EMS contact and dispatch validity in any pediatric population.

High non-transportation rates in a delicate population such as infants deserve further consideration. We have suggested that other needs are met through contacts with EMS. These contacts are not "unnecessary," because there is a real problem for which a family seeks a solution, and an ambulance is dispatched. However, the true character of these contacts remains unclear and needs more scrutiny. Interviews with non-transported families and children could uncover the genuine motives behind these contacts. Why did the family call the ambulance rather than using other health-care services? What did they think of non-transportation and were they satisfied with the EMS non-transport decision? Interviews could also identify whether other services could fulfill the needs of families with children.

The dispatch code "dyspnea" was associated with several undesirable outcomes, although dyspnea is one of the most common reasons for contacting the EMS for children [1, 30, 31, 63]. Analyzing this patient group more closely could thus reveal risk factors within that dispatch group to distinguish from more benign dyspnea symptoms.

This study concentrated only on the first wave of COVID-19 pandemic. More longitudinal studies could confirm or reject our preliminary findings of children being more seriously ill during the period of restriction measures. The long-term effects of restrictions could be detectable in research with a longer study period.

7 Summary and Conclusions

The following conclusions are based on this study:

Characteristics and outcomes of EMS contacts with pediatric seizure patients

Among EMS contacts with children, contacts due to seizures were frequent. The seizure patients were younger than unselected pediatric patients that had contact with EMS. The pediatric seizure patients consumed substantial resources both OOH and in-hospital. The ambulances were dispatched in the more urgent priority category, EMS transported pediatric seizure patients more often, and the transport was executed more frequently in the more urgent priority category than unselected pediatric population (Table 7). Vital signs were not systematically documented. Invasive measures were seldom necessary. At the ED, complimentary studies were ordered and medication adjusted. One third of patients was admitted to the hospital and follow-up visits were scheduled to half of the patients. Febrile seizures were diagnosed in 48 % of patients and 29.1% of contacts that resulted in the ED visit, were in patients with previously diagnosed epilepsy. The long-term outcomes of children who had had the EMS contact due to seizure, were good.

Characteristics and outcomes of EMS contacts with infants

Infants comprised 0.4% of all EMS missions and formed a distinguished group among EMS contacts with children. Over half of the infant contacts were dispatched within following categories: "dyspnea", "low-energy fall" and "choking". Every second contact was dispatched as non-urgent and six out of ten contacts (60%) resulted in non-transportation. Vital-sign documentation was insufficient and missing in 15% of contacts. Infants who had ED contact, were easily hospitalized. However, PICU admissions were rare.

Characteristics and outcomes of children that were evaluated, but not transported by ambulance

Non-transportation in EMS contacts with children were common and proportion varied across subpopulations. The missions were mostly dispatched as non-urgent. The following were the most frequent dispatch categories among non-transported children: "low-energy fall", "dyspnea", and "sudden deterioration of medical condition". The number of non-transported patients that contacted ED after the EMS contact, varied from 54 % in pediatric seizure patients to 17% in unselected pediatric population. The unscheduled visits of non-transported patients were, however, rare. Also, adverse outcomes after non-transportation were uncommon. The high non-transportation rate may indicate the changing role of EMS contacts in fulfilling not only health-related, but also other needs of families with children.

Identifiable risk factors for secondary outcomes in EMS contacts with children

Following factors were associated with unintended ED visits in pediatric non-transported population: dispatch codes "dyspnea", "vomiting /diarrhea", or "mental illness", younger age, night shift of EMS personnel, and time around 22:00. On the other hand, dispatch codes "low-energy fall" or "allergic reaction" were associated with less visits.

In infants, following untoward associations were established:

- medical state other than good was associated with dispatch codes "dyspnea" and "seizure", and previous P- or Q-category ICD-10 diagnosis
- medication or respiratory support at ED were associated with dispatch codes "dyspnea", "seizure", "allergic reaction", nighttime and older infants
- hospitalization was associated with dispatch codes "dyspnea", "seizure", "urgent dispatch before symptom code known", previous P- or Q-category ICD-10 diagnosis, night time and younger infants
- PICU admission was associated with dispatch codes "dyspnea", "urgent dispatch before symptom-specific code known", previous P- category ICD-10 diagnosis, younger infants, and previous EMS contact within 72 hours
- surgical procedures were associated with dispatch codes "choking", previous EMS contact within 72 hours, older infants and afternoon

Also, positive associations were noticed among infants:

- EMS personnel omission of vital-sign documentation and dispatch codes "low-energy fall" and "choking" were associated with better medical condition on arrival at ED, less medication or respiratory support and hospitalization
- dispatch code "slow deterioration of medical state" was associated with less hospitalization
- dispatch codes "dyspnea" and "low-energy fall" were associated with less surgical procedures
- dispatch code "low-energy fall" was associated with less PICU admissions

Whether and how COVID-19 pandemic and restrictions designed to curb it impacted OOH emergencies in pediatric population during the first wave

The number of EMS contacts with children decreased during the first wave of COVID-19 pandemic. However, children seemed to be more ill and the proportion of dispatch and transportation in the most urgent priority A category rose remarkably. Also, additional assistance and MICU were more often requested to the scene. Moreover, EMS personnel encountered more dead children on-scene during the study period than during the control periods, although the difference did not reach the significance level due to rarity of death in pediatric population. The proportion of patients not transported to ED rose considerably during the pandemic. COVID-19 infection among children who had EMS contact, was rare.

References

[1] H. Harve, H. Salmi, E. Rahiala, P. Pohjalainen, and M. Kuisma, "Out-of-hospital paediatric emergencies: a prospective, population-based study," *Acta Anaesthesiologica Scandinavica*, vol. 60, pp. 360–369, mar 2016.

[2] Institute of Medicine, *Emergency Care for Children.* Washington, D.C.: National Academies Press, may 2007.

[3] K. Andersen, S. Mikkelsen, G. Jørgensen, and S. T. Zwisler, "Paediatric medical emergency calls to a Danish Emergency Medical Dispatch Centre: a retrospective, observational study.," *Scandinavian journal of trauma, resuscitation and emergency medicine*, vol. 26, p. 2, jan 2018.

[4] S. U. Lee, D. Suh, H. B. Kim, J. H. Jung, K. J. Hong, J. H. Lee, H. Y. Jang, H. Noh, J. Y. Jung, D. K. Kim, and Y. H. Kwak, "Epidemiology of prehospital emergency medical service use in Korean children," *Clinical and Experimental Emergency Medicine*, vol. 4, pp. 102–108, jun 2017.

[5] J. Richard, M. H. Osmond, L. Nesbitt, and I. G. Stiell, "Management and outcomes of pediatric patients transported by emergency medical services in a Canadian prehospital system.," *CJEM*, vol. 8, pp. 6–12, jan 2006.

[6] A. Y. Corrales and M. Starr, "Assessment of the unwell child.," *Australian family physician*, vol. 39, pp. 270–5, may 2010.

[7] E. K. Cottrell, K. O'Brien, M. Curry, G. D. Meckler, P. P. Engle, J. Jui, C. Summers, W. Lambert, and J.-M. Guise, "Understanding safety in prehospital emergency medical services for children.," *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, vol. 18, no. 3, pp. 350–8, 2014.

[8] J. M. Carey, J. R. Studnek, L. R. Browne, D. G. Ostermayer, T. Grawey, S. Schroter, E. B. Lerner, and M. I. Shah, "Paramedic-Identified Enablers of and Barriers to Pediatric Seizure Management: A Multicenter, Qualitative Study," *Prehospital Emergency Care*, vol. 23, pp. 870–881, nov 2019.

[9] N. Patel, D. Ram, N. Swiderska, L. D. Mewasingh, R. W. Newton, and M. Offringa, "Febrile seizures," *BMJ (Online)*, vol. 351, no. August, pp. 1–7, 2015.

[10] M. Gaínza-Lein, I. Sánchez Fernández, M. Jackson, N. S. Abend, R. Arya, J. N. Brenton, J. L. Carpenter, K. E. Chapman, W. D. Gaillard, T. A. Glauser, J. L. Goldstein, H. P. Goodkin, K. Kapur, M. A. Mikati, K. Peariso, R. C. Tasker, D. Tchapyjnikov, A. A. Topjian, M. S. Wainwright, A. Wilfong, K. Williams, and

T. Loddenkemper, “Association of Time to Treatment With Short-term Outcomes for Pediatric Patients With Refractory Convulsive Status Epilepticus,” *JAMA Neurology*, vol. 75, p. 410, apr 2018.

[11] P. Demaret, F. Lebrun, P. Devos, C. Champagne, R. Lemaire, I. Loeckx, M. Messens, and A. Mulder, “Pediatric pre-hospital emergencies in Belgium: a 2-year national descriptive study.,” *European journal of pediatrics*, vol. 175, pp. 921–30, Jul 2016.

[12] G. Meckler, M. Hansen, W. Lambert, K. O’Brien, C. Dickinson, K. Dickinson, J. Van Otterloo, and J.-M. Guise, “Out-of-Hospital Pediatric Patient Safety Events: Results of the CSI Chart Review,” *Prehospital Emergency Care*, vol. 22, pp. 290–299, may 2018.

[13] S. Ramgopal, J. Elmer, J. Escajeda, and C. Martin-Gill, “Differences in Prehospital Patient Assessments for Pediatric Versus Adult Patients.,” *The Journal of pediatrics*, vol. 199, pp. 200–205.e6, aug 2018.

[14] M. K. Miller, M. Denise Dowd, M. C. Gratton, J. Cai, and S. D. Simon, “Pediatric out-of-hospital emergency medical services utilization in Kansas City, Missouri.,” *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine*, vol. 16, pp. 526–31, jun 2009.

[15] M. Öberg, V. Vicente, and A. C. Wahlberg, “The Emergency Medical Service personnel’s perception of the transportation of young children.,” *International emergency nursing*, vol. 23, pp. 133–7, apr 2015.

[16] J.-M. Guise, G. Meckler, K. O’Brien, M. Curry, P. Engle, C. Dickinson, K. Dickinson, M. Hansen, and W. Lambert, “Patient Safety Perceptions in Pediatric Out-of-Hospital Emergency Care: Children’s Safety Initiative.,” *The Journal of pediatrics*, vol. 167, pp. 1143–8.e1, Nov 2015.

[17] D. Jaslow, J. A. Barbera, E. Johnson, and W. Moore, “EMS-initiated refusal and alternative methods of transport.,” *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, vol. 2, no. 1, pp. 18–22, 1998.

[18] R. H. Ebben, L. C. Vloet, R. F. Speijers, N. W. Tönjes, J. Loef, T. Pelgrim, M. Hoogeveen, and S. A. Berben, “A patient-safety and professional perspective on non-conveyance in ambulance care: a systematic review,” *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 25, no. 1, p. 71, 2017.

[19] M. Hoikka, T. Silfvast, and T. I. Ala-Kokko, “A high proportion of prehospital emergency patients are not transported by ambulance: a retrospective cohort study

in Northern Finland," *Acta Anaesthesiologica Scandinavica*, vol. 61, no. 5, pp. 549–556, 2017.

[20] K. P. Hartnett, A. Kite-Powell, J. DeVies, M. A. Coletta, T. K. Boehmer, J. Adjemian, and A. V. Gundlapalli, "Impact of the COVID-19 Pandemic on Emergency Department Visits — United States, January 1, 2019–May 30, 2020," *MMWR. Morbidity and Mortality Weekly Report*, vol. 69, pp. 699–704, jun 2020.

[21] H.-Y. Lo, S.-C. Lin, C.-H. Chaou, Y.-C. Chang, C.-J. Ng, and S.-Y. Chen, "What is the impact of the COVID-19 pandemic on emergency medicine residency training: an observational study.," *BMC medical education*, vol. 20, p. 348, oct 2020.

[22] M. L. Ciofi degli Atti, A. Campana, A. O. Muda, C. Concato, L. Ravà, L. Ricotta, A. Reale, M. Barbieri, P. D'Argenio, L. Lancella, A. Villani, and M. Raponi, "Facing SARS-CoV-2 Pandemic at a COVID-19 Regional Children's Hospital in Italy," *Pediatric Infectious Disease Journal*, vol. 39, pp. e221–e225, sep 2020.

[23] S. L. Chong, J. S. L. Soo, J. C. Allen, S. Ganapathy, K. P. Lee, A. Tyebally, C. F. Yung, K. C. Thoon, Y. H. Ng, J. Y. Oh, O. H. Teoh, Y. H. Mok, and Y. H. Chan, "Impact of COVID-19 on pediatric emergencies and hospitalizations in Singapore," *BMC Pediatrics*, vol. 20, p. 562, dec 2020.

[24] C. Davico, D. Marcotulli, C. Lux, D. Calderoni, A. Terrinoni, F. Di Santo, F. Ricci, R. Vittorini, F. Amianto, A. Urbino, M. Ferrara, and B. Vitiello, "Where have the children with epilepsy gone? An observational study of seizure-related accesses to emergency department at the time of COVID-19," *Seizure*, vol. 83, no. September, pp. 38–40, 2020.

[25] C. Dopfer, M. Wetzke, A. Zychlinsky Scharff, F. Mueller, F. Dressler, U. Baumann, M. Sasse, G. Hansen, A. Jablonka, and C. Happle, "COVID-19 related reduction in pediatric emergency healthcare utilization - A concerning trend," *BMC Pediatrics*, vol. 20, p. 427, sep 2020.

[26] A. Scaramuzza, F. Tagliaferri, L. Bonetti, M. Soliani, F. Morotti, S. Bellone, C. Cavalli, and I. Rabbone, "Changing admission patterns in paediatric emergency departments during the COVID-19 pandemic," *Archives of Disease in Childhood*, vol. 105, pp. 704.2–706, jul 2020.

[27] M. Lazzerini, E. Barbi, A. Apicella, F. Marchetti, F. Cardinale, and G. Trobia, "Delayed access or provision of care in Italy resulting from fear of COVID-19," *The Lancet Child & Adolescent Health*, vol. 4, pp. e10–e11, may 2020.

[28] E. Crawley, M. Loades, G. Feder, S. Logan, S. Redwood, and J. Macleod, "Wider collateral damage to children in the UK because of the social distancing measures

designed to reduce the impact of COVID-19 in adults," *BMJ Paediatrics Open*, vol. 4, p. e000701, may 2020.

[29] G. L. Foltin, P. Dayan, M. Tunik, M. Marr, J. Leonard, K. Brown, J. Hoyle, E. B. Lerner, and Prehospital Working Group of the Pediatric Emergency Care Applied Research Network, "Priorities for pediatric prehospital research.," *Pediatric emergency care*, vol. 26, pp. 773–7, oct 2010.

[30] C. Magnusson, J. Herlitz, T. Karlsson, and C. Axelsson, "Initial assessment, level of care and outcome among children who were seen by emergency medical services: a prospective observational study," *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 26, p. 88, dec 2018.

[31] S. Ramgopal, S. Owusu-Ansah, and C. Martin-Gill, "Factors Associated With Pediatric Nontransport in a Large Emergency Medical Services System," *Academic Emergency Medicine*, vol. 25, pp. 1433–1441, dec 2018.

[32] L. Oliveira J. e Silva, J. L. Anderson, M. F. Bellolio, R. L. Campbell, L. A. Myers, A. Luke, and M. M. Jeffery, "Pediatric emergency medical services in privately insured patients: A 10-year national claims analysis," *American Journal of Emergency Medicine*, vol. 37, no. 8, pp. 1409–1415, 2019.

[33] C. L. Barker and A. D. Weatherall, "Prehospital paediatric emergencies treated by an Australian helicopter emergency medical service.," *European journal of emergency medicine : official journal of the European Society for Emergency Medicine*, vol. 21, pp. 130–5, apr 2014.

[34] C. Eich, S. G. Russo, J. F. Heuer, A. Timmermann, U. Gentkow, M. Quintel, and M. Roessler, "Characteristics of out-of-hospital paediatric emergencies attended by ambulance- and helicopter-based emergency physicians.," *Resuscitation*, vol. 80, pp. 888–92, aug 2009.

[35] P. Dayal, T. Horeczko, C. Wraa, L. Karsteadt, W. Chapman, L. Bruhnke, R. Litman, T. Ruttan, N. Kuppermann, and J. Marcin, "Emergency Medical Services Utilization by Children.," *Pediatric emergency care*, vol. 00, pp. 1–6, apr 2017.

[36] C. J. Haines, R. E. Lutes, M. Blaser, and N. C. Christopher, "Paramedic initiated non-transport of pediatric patients," *Prehospital Emergency Care*, vol. 10, no. 2, pp. 213–219, 2006.

[37] M. Dworkin, V. Nsengimana, A. Rosenberg, J. Scott, R. Riviello, E. Krebs, C. Umuhoza, E. Ntaganda, J. M. Uwitonze, I. Kabagema, T. Dushime, and S. Jayaraman, "Prehospital epidemiology and management of injured children in Kigali, Rwanda," *Emergency Medicine Journal*, vol. 37, no. 3, pp. 146–150, 2020.

[38] E. R. Alpern, R. M. Stanley, M. H. Gorelick, A. Donaldson, S. Knight, S. J. Teach, T. Singh, P. Mahajan, J. G. Goepp, N. Kuppermann, J. M. Dean, and J. M. Chamberlain, "Epidemiology of a pediatric emergency medicine research network: The PECARN core data project," *Pediatric Emergency Care*, vol. 22, no. 10, pp. 689–699, 2006.

[39] M. N. Shah, J. T. Cushman, C. O. Davis, J. J. Bazarian, P. Auinger, and B. Friedman, "The epidemiology of emergency medical services use by children: an analysis of the National Hospital Ambulatory Medical Care Survey.," *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, vol. 12, pp. 269–76, jan 2008.

[40] K. Bohm and L. Kurland, "The accuracy of medical dispatch - a systematic review.," *Scandinavian journal of trauma, resuscitation and emergency medicine*, vol. 26, p. 94, nov 2018.

[41] D. Lockey, "International EMS systems," *Resuscitation*, vol. 59, p. 163, nov 2003.

[42] D. Lockey, "International EMS systems: Geographical lottery and diversity but many common challenges.," *Resuscitation*, vol. 80, p. 722, jul 2009.

[43] C. N. Pozner, R. Zane, S. J. Nelson, and M. Levine, "International EMS Systems: The United States: Past, present, and future," *Resuscitation*, vol. 60, no. 3, pp. 239–244, 2004.

[44] A. Langhelle, H. M. Lossius, T. Silfvast, H. M. Björnsson, F. K. Lippert, A. Ersson, and E. Søreide, "International EMS Systems: The Nordic countries," *Resuscitation*, vol. 61, no. 1, pp. 9–21, 2004.

[45] K. K. Hung, C. S. Cheung, T. H. Rainer, and C. A. Graham, "EMS systems in China," *Resuscitation*, vol. 80, no. 7, pp. 732–735, 2009.

[46] T. A. Lindskou, S. Mikkelsen, E. F. Christensen, P. A. Hansen, G. Jørgensen, O. M. Hendriksen, H. Kirkegaard, P. A. Berlac, and M. B. Søvsø, "The Danish prehospital emergency healthcare system and research possibilities," *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 27, p. 100, dec 2019.

[47] S. Trevithick, A. Flabouris, G. Tall, and C. F. Webber, "International EMS systems: New South Wales, Australia," *Resuscitation*, vol. 59, no. 2, pp. 165–170, 2003.

[48] D. Y. Ellis and E. Sorene, "Magen David Adom-The EMS in Israel," *Resuscitation*, vol. 76, no. 1, pp. 5–10, 2008.

[49] M. Roessler and O. Zuzan, "EMS systems in Germany," *Resuscitation*, vol. 68, pp. 45–49, jan 2006.

[50] J. J. Black and G. D. Davies, "International EMS Systems: United Kingdom," *Resuscitation*, vol. 64, no. 1, pp. 21–29, 2005.

[51] "Ensihoidon laskutus — Helsingin kaupunki," https://www.hel.fi/pela/fi/palaute/palvelut/palvelukuvaus?id=5179, Accessed 16 May 2021.

[52] M. Kuisma, P. Holmström, J. Nurmi, K. Porthan, and T. Taskinen, *Ensihoito*. Helsinki: Sanoma Pro Oy, 3., uudist ed., 2013.

[53] A. Tsai and G. Kallsen, "Epidemiology of pediatric prehospital care," *Annals of Emergency Medicine*, vol. 16, pp. 284–292, mar 1987.

[54] H. E. Wang, N. C. Mann, K. E. Jacobson, M. D. MS, G. Mears, K. Smyrski, and D. M. Yealy, "National Characteristics of Emergency Medical Services Responses in the United States," *Prehospital Emergency Care*, vol. 17, pp. 8–14, jan 2013.

[55] C. E. McConnel and R. W. Wilson, "Racial and ethnic patterns in the utilization of prehospital emergency transport services in the United States.," *Prehospital and disaster medicine*, vol. 14, no. 4, pp. 232–5, 1999.

[56] J. Ellbrant, J. Åkeson, J. Eckner, and P. Karlsland Åkeson, "Influence of social characteristics on use of paediatric emergency care in Sweden - A questionnaire based study," *BMC Emergency Medicine*, vol. 18, no. 1, pp. 1–8, 2018.

[57] F. S. Mendoza, "Health Disparities and Children in Immigrant Families: A Research Agenda," *Pediatrics*, vol. 124, pp. S187–S195, nov 2009.

[58] S. A. McGee and L. Claudio, "Nativity as a Determinant of Health Disparities Among Children," *Journal of Immigrant and Minority Health*, vol. 20, pp. 517–528, jun 2018.

[59] H. Salmi, M. Kuisma, E. Rahiala, M. Lääperi, and H. Harve-Rytsälä, "Children in disadvantaged neighbourhoods have more out-of-hospital emergencies: a population-based study.," *Archives of disease in childhood*, vol. 103, pp. 1048–1053, may 2018.

[60] I. Listo, H. Salmi, M. Hästbacka, M. Lääperi, J. Oulasvirta, T. Etelälahti, M. Kuisma, and H. Harve-Rytsälä, "Pediatric traumas and neighborhood socioeconomic characteristics: A population based study," *Journal of Pediatric Surgery*, vol. 56, pp. 760–767, apr 2021.

[61] L. A. Diggs, M. Sheth-Chandra, and G. De Leo, "Epidemiology of Pediatric Prehospital Basic Life Support Care in the United States," *Prehospital Emergency Care*, vol. 20, pp. 230–238, mar 2016.

[62] P. C. Drayna, L. R. Browne, C. E. Guse, D. C. Brousseau, and E. B. Lerner, "Prehospital Pediatric Care: Opportunities for Training, Treatment, and Research.," *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, vol. 19, no. 3, pp. 441–7, 2015.

[63] E. B. Lerner, P. S. Dayan, K. Brown, S. Fuchs, J. Leonard, D. Borgialli, L. Babcock, J. D. Hoyle, M. Kwok, K. Lillis, L. E. Nigrovic, P. Mahajan, A. Rogers, H. Schwartz, J. Soprano, N. Tsarouhas, S. Turnipseed, T. Funai, G. Foltin, and Pediatric Emergency Care Applied Research Network (PECARN), "Characteristics of the pediatric patients treated by the Pediatric Emergency Care Applied Research Network's affiliated EMS agencies.," *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, vol. 18, no. 1, pp. 52–9, 2013.

[64] N. Kannikeswaran, P. V. Mahajan, R. B. Dunne, S. Compton, and S. R. Knazik, "Epidemiology of pediatric transports and non-transports in an urban emergency medical services system," *Prehospital Emergency Care*, vol. 11, no. 4, pp. 403–407, 2007.

[65] S. Kost, K. Cronan, M. Gorelick, and J. Arruda, "Ambulance use by high-acuity patients in a pediatric ED," *The American Journal of Emergency Medicine*, vol. 18, pp. 679–682, oct 2000.

[66] J. T. Cushman, R. J. Fairbanks, K. G. O'Gara, C. N. Crittenden, E. C. Pennington, M. A. Wilson, N. P. Chin, and M. N. Shah, "Ambulance personnel perceptions of near misses and adverse events in pediatric patients.," *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors*, vol. 14, pp. 477–84, aug 2010.

[67] J. Fowler, B. Beovich, and B. Williams, "Improving paramedic confidence with paediatric patients : A scoping review," *Australasian Journal of Paramedicine*, vol. 15, no. 1, 2017.

[68] J.-M. Guise, M. Hansen, K. O'Brien, C. Dickinson, G. Meckler, P. Engle, W. Lambert, and J. Jui, "Emergency medical services responders' perceptions of the effect of stress and anxiety on patient safety in the out-of-hospital emergency care of children: a qualitative study," *BMJ Open*, vol. 7, p. e014057, feb 2017.

[69] A. R. Corfield, L. Clerihew, E. Stewart, H. Staines, D. Tough, and K. D. Rooney, "The discrimination of quick Paediatric Early Warning Scores in the pre-hospital setting," *Anaesthesia*, vol. 75, pp. 353–358, mar 2020.

[70] R. S. Fisher, W. v. E. Boas, W. Blume, C. Elger, P. Genton, P. Lee, and J. Engel, "Epileptic Seizures and Epilepsy: Definitions Proposed by the International League Against Epilepsy (ILAE) and the International Bureau for Epilepsy (IBE)," *Epilepsia*, vol. 46, pp. 470–472, apr 2005.

[71] R. S. Fisher, C. Acevedo, A. Arzimanoglou, A. Bogacz, J. H. Cross, C. E. Elger, J. Engel, L. Forsgren, J. A. French, M. Glynn, D. C. Hesdorffer, B. Lee, G. W. Mathern, S. L. Moshé, E. Perucca, I. E. Scheffer, T. Tomson, M. Watanabe, and S. Wiebe, "ILAE Official Report: A practical clinical definition of epilepsy," *Epilepsia*, vol. 55, pp. 475–482, apr 2014.

[72] J. J. Falco-Walter, I. E. Scheffer, and R. S. Fisher, "The new definition and classification of seizures and epilepsy," *Epilepsy Research*, vol. 139, pp. 73–79, jan 2018.

[73] S. Varnado and D. Price, "Basics of modern epilepsy classification and terminology," *Current Problems in Pediatric and Adolescent Health Care*, vol. 50, no. 11, p. 100891, 2020.

[74] K. Mikkonen, M. Uhari, T. Pokka, and H. Rantala, "Diurnal and seasonal occurrence of febrile seizures.," *Pediatric neurology*, vol. 52, pp. 424–7, apr 2015.

[75] A. Neligan, A. J. Noyce, T. D. Gosavi, S. D. Shorvon, S. Köhler, and M. C. Walker, "Change in Mortality of Generalized Convulsive Status Epilepticus in High-Income Countries over Time: A Systematic Review and Meta-analysis," aug 2019.

[76] M. I. Shah, C. G. Macias, P. S. Dayan, T. S. Weik, K. M. Brown, S. M. Fuchs, M. E. Fallat, J. L. Wright, and E. S. Lang, "An Evidence-based Guideline for Pediatric Prehospital Seizure Management Using GRADE Methodology," *Prehospital Emergency Care*, vol. 18, pp. 15–24, jan 2014.

[77] G. Vitaliti, E. Castagno, F. Ricceri, A. Urbino, A. V. Di Pianella, R. Lubrano, E. Caramaschi, M. Prota, R. M. Pulvirenti, P. Ajovalasit, G. Signorile, C. Navone, M. R. La Bianca, A. Villani, G. Corsello, and R. Falsaperla, "Epidemiology and diagnostic and therapeutic management of febrile seizures in the Italian pediatric emergency departments: A prospective observational study," *Epilepsy Research*, vol. 129, pp. 79–85, jan 2017.

[78] B. Lawton and N. Deuble, "Seizures in the paediatric emergency department," *Journal of Paediatrics and Child Health*, vol. 52, pp. 147–150, feb 2016.

[79] M. M. Martinos, M. Yoong, S. Patil, R. F. Chin, B. G. Neville, R. C. Scott, and M. De Haan, "Recognition memory is impaired in children after prolonged febrile seizures," *Brain*, vol. 135, no. 10, pp. 3153–3164, 2012.

[80] H. Cass and H. Emery, “Why children die: Death in infants, children and young people in the UK. Part B,” Tech. Rep. May, Royal College of Paediatrics and Child Health National Children’s Bureau, London, 2014.

[81] N. Rosenberg, S. Knazik, S. Cohen, and P. Simpson, “Use of Emergency Medical Service transport system in medical patients up to 36 months of age.,” *Pediatric emergency care*, vol. 14, pp. 191–3, jun 1998.

[82] K. Camasso-Richardson, J. A. Wilde, and E. M. Petrack, “Medically unnecessary pediatric ambulance transports: a medical taxi service?,” *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine*, vol. 4, pp. 1137–41, dec 1997.

[83] S. Kost and J. Arruda, “Appropriateness of ambulance transportation to a suburban pediatric emergency department,” *Prehospital Emergency Care*, vol. 3, pp. 187–190, jan 1999.

[84] A. H. Rominger, M. J. Smith, and M. D. Stevenson, “Emergency medical services system utilization over the last 10 years: what predicts transport of children?,” *Pediatric emergency care*, vol. 31, pp. 321–6, may 2015.

[85] M. M. Corrado, J. Shi, K. K. Wheeler, J. Peng, B. Kenney, S. Johnson, and H. Xiang, “Emergency medical services (EMS) versus non-EMS transport among injured children in the United States,” *The American Journal of Emergency Medicine*, vol. 35, pp. 475–478, mar 2017.

[86] J. H. Rubens, O. Z. Ahmed, G. Yenokyan, D. Stewart, R. S. Burd, and L. M. Ryan, “Mode of Transport and Trauma Activation Status in Admitted Pediatric Trauma Patients,” *Journal of Surgical Research*, vol. 246, no. May 2018, pp. 153–159, 2020.

[87] M. E. Richards, M. W. Hubble, and S. Zwehl-Burke, “”Inappropriate” pediatric emergency medical services utilization redefined.,” *Pediatric emergency care*, vol. 27, pp. 514–8, jun 2011.

[88] R. H. Woods, M. Shah, C. Doughty, and A. Gilchrest, “A Survey of Restraint Methods for the Safe Transport of Children in Ground Ambulances.,” *Pediatric emergency care*, vol. 34, pp. 149–153, mar 2018.

[89] J. O’Neil, G. K. Steele, E. Weinstein, R. Collins, J. Talty, and M. J. Bull, “Ambulance transport of noncritical children: emergency medical service providers’ knowledge, opinions, and practice.,” *Clinical pediatrics*, vol. 53, pp. 250–5, mar 2014.

[90] B. Murray and R. Kue, “The Use of Emergency Lights and Sirens by Ambulances and Their Effect on Patient Outcomes and Public Safety: A Comprehensive Review

of the Literature," *Prehospital and Disaster Medicine*, vol. 32, pp. 209–216, apr 2017.

[91] F. M. Mix, L. A. Myers, A. Luke, and M. D. Sztajnkrycer, "A Descriptive Analysis of Pediatric Prehospital Refusal of Medical Assistance Within a Single Service Provider System," *Pediatric Emergency Care*, vol. 36, pp. 26–30, jan 2020.

[92] J. Kahalé, M. H. Osmond, L. Nesbitt, and I. G. Stiell, "What Are the Characteristics and Outcomes of Nontransported Pediatric Patients?," *Prehospital Emergency Care*, vol. 10, pp. 28–34, jan 2006.

[93] G. R. Gerlacher, P. E. Sirbaugh, and C. G. Macias, "Prehospital evaluation of non-transported pediatric patients by a large emergency medical services system," *Pediatric Emergency Care*, vol. 17, no. 6, pp. 421–424, 2001.

[94] A. G. Seltzer, G. M. Vilke, T. C. Chan, R. Fisher, and J. V. Dunford, "Outcome study of minors after parental refusal of paramedic transport," *Prehospital Emergency Care*, vol. 5, no. 3, pp. 278–283, 2001.

[95] N. S. Mehta, O. T. Mytton, E. W. Mullins, T. A. Fowler, C. L. Falconer, O. B. Murphy, C. Langenberg, W. J. Jayatunga, D. H. Eddy, and J. S. Nguyen-Van-Tam, "SARS-CoV-2 (COVID-19): What Do We Know about Children? A Systematic Review," *Clinical Infectious Diseases*, vol. 71, no. 9, pp. 2469–2479, 2020.

[96] C. A. Pollard, M. P. Morran, and A. L. Nestor-Kalinoski, "The COVID-19 pandemic: a global health crisis," *Physiological Genomics*, vol. 52, pp. 549–557, nov 2020.

[97] M. S. Gold, D. Sehayek, S. Gabrielli, X. Zhang, C. McCusker, and M. Ben-Shoshan, "COVID-19 and comorbidities: a systematic review and meta-analysis.," *Postgraduate medicine*, vol. 132, pp. 749–755, nov 2020.

[98] D. Wolff, S. Nee, N. S. Hickey, and M. Marschollek, "Risk factors for Covid-19 severity and fatality: a structured literature review," *Infection*, vol. 49, pp. 15–28, feb 2021.

[99] N. A. Patel, "Pediatric COVID-19: Systematic review of the literature," *American Journal of Otolaryngology - Head and Neck Medicine and Surgery*, vol. 41, no. 5, p. 102573, 2020.

[100] J. Yasuhara, T. Kuno, H. Takagi, and N. Sumitomo, "Clinical characteristics of COVID-19 in children: A systematic review," *Pediatric Pulmonology*, vol. 55, no. 10, pp. 2565–2575, 2020.

[101] M. U. Bhuiyan, E. Stiboy, M. Z. Hassan, M. Chan, M. S. Islam, N. Haider, A. Jaffe, and N. Homaira, "Epidemiology of COVID-19 infection in young children under five years: A systematic review and meta-analysis," *Vaccine*, vol. 39, no. 4, pp. 667–677, 2021.

[102] WHO, "Timeline of WHO's response to COVID-19," https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!; Accessed 14 Feb 2021.

[103] B. Dicker, A. Swain, V. F. Todd, B. Tunnage, E. McConachy, H. Drake, M. Brett, D. Spearing, and G. J. Howie, "Changes in demand for emergency ambulances during a nationwide lockdown that resulted in elimination of COVID-19: An observational study from New Zealand," *BMJ Open*, vol. 10, no. 12, 2020.

[104] J. L. Holmes, S. Brake, M. Docherty, R. Lilford, and S. Watson, "Emergency ambulance services for heart attack and stroke during UK's COVID-19 lockdown," *The Lancet*, vol. 395, pp. e93–e94, may 2020.

[105] F. Carrat, M. Touvier, G. Severi, L. Meyer, F. Jusot, N. Lapidus, D. Rahib, N. Lydié, M.-A. Charles, P.-Y. Ancel, A. Rouquette, X. de Lamballerie, M. Zins, and N. Bajos, "Incidence and risk factors of COVID-19-like symptoms in the French general population during the lockdown period: a multi-cohort study," *BMC Infectious Diseases*, vol. 21, p. 169, dec 2021.

[106] "Sweden has avoided a COVID-19 lockdown so far: Has its strategy worked? - ABC News," https://abcnews.go.com/International/sweden-avoided-covid-19-lockdown-strategy-worked/story?id=76047258; Accessed 21 May 2021.

[107] "Timeline of the COVID-19 pandemic - Wikipedia," https://en.wikipedia.org/wiki/Timeline_of_the_COVID-19_pandemic; Accessed 22 May 2021.

[108] "Suomen koronaviruspandemian aikajana – Wikipedia," https://fi.wikipedia.org/wiki/Suomen_koronaviruspandemian_aikajana; Accessed 22 May 2021.

[109] Finnish Government Official, "Prime Minister Sanna Marin explains Government's hybrid strategy in Friday briefing, modelling and indicators also on the agenda," https://valtioneuvosto.fi/en/-//10616/paaministeri-sanna-marin-avasi-hallituksen-hybridistrategiaa-myos-mallinnukset-ja-mittarit-esilla-perjantain-tilannekatsausinfossa; Accessed 14 Feb 2021.

[110] Finnish Government Official, "Government Resolution on a plan for a hybrid strategy to manage the COVID-19 crisis," https://valtioneuvosto.fi/en/-//10616/valtioneuvoston-periaatepaatos-suunnitelmasta-koronakriisin-hallinnan-hybridistrategiaksi; Accessed 14 Feb 2021.

[111] P. Green, "Risks to children and young people during covid-19 pandemic," *BMJ*, vol. 369, p. m1669, apr 2020.

[112] E. B. Lerner, C. D. Newgard, and N. C. Mann, "Effect of the Coronavirus Disease 2019 (COVID-19) Pandemic on the U.S. Emergency Medical Services System: A Preliminary Report," *Academic Emergency Medicine*, vol. 27, no. 8, pp. 693–699, 2020.

[113] H. Salmi, H. Harve-Rytsälä, P. Rautiainen, S. Pyörälä, and J. Hästbacka, "Overlooking the Obvious during the COVID-19 Pandemic: Dyspnoea with Asymmetric Breath Sounds in a Toddler," *Case Reports in Pediatrics*, vol. 2021, pp. 1–4, 2021.

[114] R. Kyeremateng, L. Oguda, and O. Asemota, "COVID-19 pandemic: health inequities in children and youth," *Archives of Disease in Childhood*, vol. 0, pp. archdischild–2020–320170, feb 2021.

[115] European Academy of Paediatrics, "TAKE ACTION NOW TO COUNTER THE EFFECT OF COVID ON EUROPE'S CHILDREN AND PUT THEIR NEEDS FIRST SAY PAEDIATRIC LEADERS," https://www.eapaediatrics.eu/eap-initiative-international-policy-for-childrens-health/; Accessed 14 Feb 2021.

[116] ICD-10, "ICD-10 Version:2019," https://icd.who.int/browse10/2019/en; Accessed 21 Jun 2020.

[117] Statistics Finland, "Finnish Official Statistics - Suomen virallinen tilasto (SVT): Population structure [verkkojulkaisu]. ISSN=1797-5379. Helsinki: Tilastokeskus," http://tilastokeskus.fi/til/vaerak/2017/index_en.html; Accessed 30 Dec 2019.

[118] M. Hoikka, S. Länkimäki, T. Silfvast, and T. I. Ala-Kokko, "Medical priority dispatch codes—comparison with National Early Warning Score," *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 24, p. 142, dec 2016.

[119] R Core Team, "R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.," 2020.

[120] H. Wickham, *ggplot2: Elegant Graphics for Data Analysis.* Use R!, Cham: Springer International Publishing, 2016.

[121] H. Hewes, S. Hunsaker, M. Christensen, J. Whitney, T. Dalrymple, and P. Taillac, "Documentation of pediatric vital signs by EMS providers over time," *Journal of Pediatric Surgery*, vol. 51, pp. 329–332, feb 2016.

[122] A. Ehara and E. Yoshioka, "Emergency transport for Japanese children with non-life-threatening conditions.," *Pediatrics international : official journal of the Japan Pediatric Society*, vol. 54, pp. 244–7, apr 2012.

[123] R. Isba, R. Edge, R. Jenner, E. Broughton, N. Francis, and J. Butler, "Where have all the children gone? Decreases in paediatric emergency department attendances at the start of the COVID-19 pandemic of 2020," *Archives of Disease in Childhood*, vol. 105, no. 7, p. 2020, 2020.

[124] S. Albuquerque and A. R. Santos, ""In the Same Storm, but Not on the Same Boat": Children Grief During the COVID-19 Pandemic," *Frontiers in Psychiatry*, vol. 12, no. January, pp. 10–13, 2021.

[125] R. Takaku and I. Yokoyama, "What the COVID-19 School Closure Left in Its Wake: Evidence from a Regression Discontinuity Analysis in Japan," *Journal of Public Economics*, vol. 195, p. 104364, 2021.

[126] J. Y.-H. Wong, A. K.-C. Wai, M. P. Wang, J. J. Lee, M. Li, J. Y.-Y. Kwok, C. K.-H. Wong, and A. W.-M. Choi, "Impact of COVID-19 on Child Maltreatment: Income Instability and Parenting Issues," *International Journal of Environmental Research and Public Health*, vol. 18, p. 1501, feb 2021.

[127] J. N. Jeruzal, L. L. Boland, M. S. Frazer, J. W. Kamrud, R. N. Myers, C. J. Lick, and A. C. Stevens, "Emergency Medical Services Provider Perspectives on Pediatric Calls: A Qualitative Study," *Prehospital Emergency Care*, vol. 23, pp. 501–509, jul 2019.

[128] J. Paulin, J. Kurola, S. Salanterä, H. Moen, N. Guragain, M. Koivisto, N. Käyhkö, V. Aaltonen, and T. Iirola, "Changing role of EMS –analyses of non-conveyed and conveyed patients in Finland," *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, vol. 28, p. 45, dec 2020.

[129] L. D. Frenkel, F. Gomez, and J. A. Bellanti, "COVID-19 in children: Pathogenesis and current status," *Allergy and Asthma Proceedings*, vol. 42, no. 1, pp. 8–15, 2021.

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